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The editors of this journal wish to thank Dr. Juan M. Sanchez, Vice President for the Research, Dr. Juan C. González, Vice President for Student Affairs, Dr. Lucia Gilbert, Vice Provost, Dr. Sarah Simmons, Natural Sciences Undergraduate Research Program Coordinator, and Lynda Gonzalez, Research Coordinator for their generous support and guidance.

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They offer their appreciation as well to Ms. Christine Henke, Ms. Annie Elderbroom, Ms. Becky Carreon, Ms. Donna Bellinghausen, and the Senate of College Councils for helping make the UT Austin Undergraduate Research Journal possible.

FROM THE EDITOR

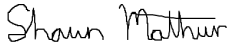
The 2007-2008 editorial staff is delighted to present the seventh edition of The University of Texas at Austin Undergraduate Research Journal (URJ). The URJ was founded with the intent to recognize outstanding student research conducted on campus and encourage a passion for learning, creativity and discovery. As a multidisciplinary publication, the URJ offers a forum for students of all majors to discuss and explore their interest in research. The high-quality of undergraduate research taking place at UT-Austin is reflected in the insightful, well-written manuscripts submitted to the URJ for publication. The two-stage URJ evaluation process combines the input of students and faculty to select the best submissions. The end result is a collection of thought-provoking articles that showcases the quality and diversity of work done by UT undergraduates.

The URJ has evolved into a mature publication thanks to the support we have received from faculty and UT-Austin. We would especially like to thank Dr. Toyin Falola, Ms. Annie Elderbroom, Dr. Jonathan Koehler and Dr. Sarah Simmons for their guidance and encouragement. We greatly appreciate their dedication to student initiatives like the URJ and we are extremely fortunate to work them. Also, this year is the first time the URJ will be published by the University of Texas Printing Services. We are thankful for the assistance that UT Printing has provided to us over the summer and we look forward to their continued support. Finally, we are tremendously grateful for the funding that the URJ has received from the Office of Vice President of Research, the Office of Student Affairs and the Senate of College Councils. Their generosity makes the publication and printing of the URJ possible year after year.

The Undergraduate Research Journal has made significant progress over the years and we hope that with your support it will continue to flourish in the future. If you would like to get involved, or are interested in submitting an article for publication please visit our website at *http://www.utexas.edu/student/urj*.

Thanks for your interest in the Undergraduate Research Journal and I hope you enjoy the issue.

Sincerely,



Shawn Mathur, Editor in Chief
URJ Editorial Staff

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Not a Theological Question: Is the River Jordan Really Dammed to Hell?

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Bryan Blaisdell

School of Civil Engineering

Mark 1:5
And there went out unto him all the land of Judaea, and they of Jerusalem, and were all baptized of him in the river of Jordan, confessing their sins.

The life of the Jordan River begins in the north during a chance winter snowfall. As dense clouds congregate over Mount Hermon and part of Lebanon, the entire Jordan River Valley almost seems to hush as if prepared for its communion. From atop the mountain, fallen snowflakes melt and rejoin a network of ancient tunnels and underground springs from within to begin their journey back towards the sea. Together, they form the Banias and the Dan, as well as the Hasbani and the Asyoun, all infant tributaries that will in time converge to become the Jordan in northern Israel. The river begins its journey southward and

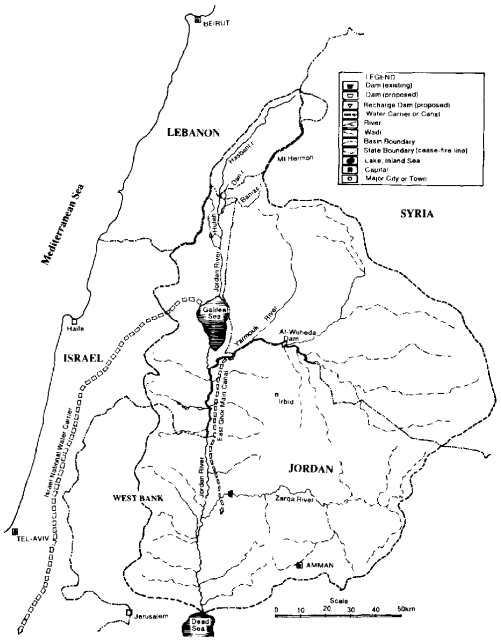
quickly fills in the reemerging swamps of Lake Hula. Fifteen miles beyond, it empties into the biblical Sea of Galilee, reforms and unites with its cousins, the Yarmouk and Zarqa, waxing sinusoidal, growing in size and losing gradient, all the while falling towards the landlocked Dead Sea.

In Hebrew, Jordan literally means "the descender," a designation aptly chosen for one of the world's most impressive waterfall displays. Over its course of seventy miles from the base of Mount Hermon to the Dead Sea, Jordan waters plummet bit by bit nearly half a mile down to the lowest point anywhere on the planet, about 1300 ft. below sea level.[1] There they retire among the world's saltiest body of water, mixing with the currents and awaiting their eventual evaporation and rebirth according to the infinite hydrological cycle.

At any given time, the Jordan River has many different faces. Most traditionally, as in the Bible, it is the sacred life-giver for aspiring Christians – it is the "garden of the Lord[2]" and said to be the river of Jesus' holy baptism. According to biblical text, it was the site of healing miracles seen by Elisha and Naaman and the site of historical battles between Gideon and the Midianites and between Jonathan and Bacchides. Muslims, too, make their pilgrimage to the banks of the Jordan to honor tombs of the Prophet Mohammad's venerable companions and military leaders who died during the Great Plague in the 18th year after the Hijra.[3] The river is a geological landmark, winding along the shifting Great Rift Valley between the African and Arabian tectonic plates. The Jordan passes between dense forests and barren deserts, giving home to a wide array of plants and wildlife, including reeds and willows, leopards, jackals, foxes, wild ducks, deer, and desert rats.[4]

At the same time, the river supplies most of the arid region's human water demands. Israel and Jordan are both heavily dependent on the river for drinking water, irrigation, and sanitation, while

Figure 1 *The Jordan River is divided into two halves: the Upper Jordan (north of the Sea of Galilee) is fed by springs, tributaries, and run-off from Lake Hula; below this, over half of the Jordan's flow comes from the Yarmouk and Zarqa Rivers. Although the Upper Jordan and Yarmouk waters are potable, they become progressively more saline as they approach the Dead Sea. Because of this, much of the Lower Jordan is virtually unusable for Israel and Jordan's municipal water demands.*



Bryan Blaisdell

Syria and Lebanon both stake their own claims in the share (see Figure 1). Within the past century, opposing countries have competed, using hydroelectric plants, dams, pipes, canals, and treatment plants all surrounding the Jordan River in attempts to declare their own right to the water supply and exert their authority over the others. This serious game of tug-o-war is gradually ballooning beyond the point of no return. As a long witness to the area's political, ethnic, and religious turmoil, the river now suffers its own tragedy from overuse and pollution due to agricultural runoff and raw sewage discharge. These abuses have damaged the river's ecosystem and put an enormous stress on its clean water supply, threatening the vital welfare of more than ten million people. Over recent years, while the demand for its water has increased, the Jordan River has been choked, diverted, and sucked dry at a rate that is clearly unsustainable. Could recent generations have dammed the holy river beyond the point of rescue? And what is left of hope for an ailing river that continues to inspire visiting pilgrims from all around the world?

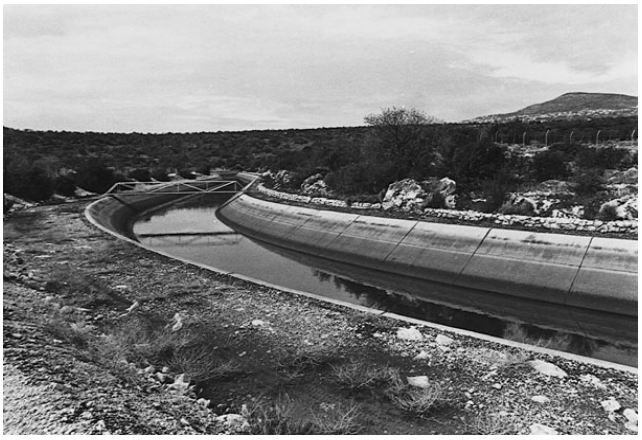
Bridge over Troubled Waters

Near Kibbutz Gesher in Israel stands a powerful symbol of the Jordan River's historical crossroads. In ancient days, as the original men crossed the valley from Africa to trade ways and war, their heavy footprints marked the lands for future horse carriages and cement trucks. Gradually, after years of operating pulley-driven ferries[5], these men evolved beyond Darwin's wildest dreams – one might imagine they became slow figures, in fact, almost like stone statues, and they grew hands and feet like abutments. Their perfectly adapted forms stretched and arched gracefully, and bridges arose organically, where men of the earth could face the river and honor its eternal motion. Time has preserved their fossils well: the oldest of these is a 2000-year-old stone Roman bridge. Next to this is an Ottoman rail bridge made of brick, now apparently abandoned and weathering away. The third was once a British Mandate bridge, shaped early in the twentieth century to help the British Army cross into Jordan and fight the Ottomans.[6] Today, the crossing is familiarly known as "Old Bridges" by tourists.

It is here where part of the Jordan River's modern story begins – and with it, the First Arab-Israeli War. In April 1948, when the first Transjordan Arab Legion unit invaded Palestine to interdict the roads surrounding Jerusalem, it is said they crossed the Jordan by way of this bridge and attacked the small Gesher settlement. Caught off guard, fifty children from the town were sent to hide in a six-by-two-meter bunker for thirty hours. With everything surrounded, buildings around them collapsed under siege and fleeing inhabitants were met by guns and water. This was not, by any means, the river's first or last taste of blood. The Jordan River has been bothered by conflict for millennia. Archaeological evidence dating from as far back as the Bronze Age suggests that villages near the river were fortified to protect its people against a very real threat of attack.[7] Hellenistic and Roman settlements have been found scattered across the foothills and depressions of the valley (the Roman sites are usually built atop the ruins of the vanquished). In nearby Jisr Banat Ya'aqub, a site of twentieth century Israeli-Arab water conflict, ancient skeletons have been unearthed fully armed with flint and basalt axes. Oftentimes, the Jordan River has served as a barrier between enemies; at other times, it has been only a hurdle for generals. Recently, it has been caught in the escalating war of identity and political tension between Israel and the neighboring Arab world. Even the river itself has become a cause for turbulence, as water grows increasingly scarce and opposing leaders from Israel and Jordan desperately vie to quench their countries' thirsts.

By the time of the 1949 armistice agreements one year after the Gesher incident, Israel had declared itself an independent Jewish state, and the Arab world looked on with a mixture of disbelief, resentment, and hatred. As the postwar cloud thickened, neither side thought twice about negotiating water rights. Instead, each of the riparians quickly acted to develop the Jordan River unilaterally.[8] In 1951,

Figure 2 *Israel's National Water Carrier is an engineering marvel, used to supply a considerable portion of Israel's domestic water needs. It spans over 130km from the Sea of Galilee to the Negev desert region, using a series of aqueducts, tunnels, reservoirs, and pumping stations to carry the water across the uneven terrain.*



Source: Embassy of Israel, Washington

the All Israel Plan took form, leading Israel to drain Lake Hula completely and make the empty basin available for agriculture. In the process of working there, Israel violated their demilitarized zone agreements with Syria, upon which Syria retaliated both to protect their own property and to obstruct the foreign development of water resources along their borders. At the same time, Israel also began to construct a massive 130-kilometer aqueduct and pipeline network straight from the Sea of Galilee (see Figure 2). This National Water Carrier system supplied water to Israel's southern Negev desert and the entire coastal region

Almost simultaneously, the Jordanian government and the UNRWA (the United Nations Relief and Works Agency for Palestine Refugees in the Near East) began to consider other strategies, and, in the end, they agreed to implement a plan by an American engineer named M.E. Bunger. In this plan, Bunger called for two storage dams on the Yarmouk River: one at Maqarin (a 480 million m^3 capacity) and another at Addassiyah, which would help direct the flow of water into a canal along Jordan's East Ghor region. In addition, he proposed to build one hydroelectric power plant at each location. These actions were expected to help resettle 100,000 Palestinian refugees within Jordan's territory. Israel was upset by this development, and reasonably so – the Yarmouk supplies nearly half of the Jordan River's total surface water discharge. Without the Yarmouk River flowing freely, Israel would have to look elsewhere to meet its annual water budget. And in 1953, amidst Israel's protests, Jordan and Syria signed a treaty by which they would both share Yarmouk waters. As expected, Israel reacted one month later with yet another invention of their own: to take advantage of the lower salinity levels upstream, they tried, against warnings from the United Nations, to divert the Jordan River near Jisr Banat Ya'aqub within the demilitarized zone. But after the United States threatened to cut off their funding, Israel recalculated their decision and abandoned the diversion project.

Certainly, this study does not intend to dwell on the Jordan River's complicated past. But keep in mind that, in the half century since all these events occurred, water resolution has been extraordinarily difficult to attain. Bunger's plan, after all, was not adopted; neither was the so-called "Main Plan" that replaced it, or the "Cotton Plan" variation, or the "Arab Plan," or even the "Unified (Johnston)

Plan," despite its approval by both Israeli and Arab technical committees. Each of these proposals failed to establish a real political consensus regarding fair division of the Jordan River system. As a result, governments returned to their unilateral objectives, which essentially amounted to a wild arms race.

To augment their agricultural water supply using the Yarmouk River, Jordan began construction of the East Ghor Main Canal[a] in 1959, which may have been inspired by Bunger's original vision.[9] Further, they drew up plans to develop two dams along the Yarmouk (at Mukheiba and Maqarin), which they would share with Syria according to the 1953 treaty. In 1964, when Israel first began to withdraw water from the Sea of Galilee using their monumental National Water Carrier, the Arab League responded with a devious Headwater Diversion Plan. Upon completion of this plan, the Banias and Hasbani tributaries would no longer flow into Israel or the Sea of Galilee but instead would be redirected towards the dam at Mukheiba for easy access by Jordan or Syria. It was an effective passive-aggressive strike against Israel, but it did not go unchecked. The following year, Israeli Defensive Forces targeted these diversion works, inciting further border violence, which gradually escalated into the Third Arab-Israeli War in 1967. Six days after it began (hence its nickname, the "Six-Day War"), the war ended on a cease-fire agreement. Yet, even in this short time, Israel had managed to occupy much of the northern Golan Heights territory and nearly half the length of the Yarmouk River (see Figure 3). This crucial victory put Jordan and Syria at bay, making the Diversion Plan impossible to achieve within their own borders. It also suspended their Mukheiba and Maqarin dam projects indefinitely and allowed Israel to pump at will from the Sea of Galilee.

[a] Recently renamed the King Abdullah Canal (KAC)

Figure 3 | *Israel: Before and After Six-Day War, 1949-1967*

Source: Ahavat Israel

Bryan Blaisdell

More Water, Please

In the wake of the 1991 Gulf War, Middle Eastern dynamics began to shift, forming a pair of unlikely allies. A small hope arrived in 1994 with the Israel-Jordan Treaty of Peace. It was a pact signed between King Hussein of Jordan and Israel Prime Minister Yitzhak Rabin, witnessed by President Bill Clinton.[10] But amidst all the ceremony's colorful balloons, hurrahs, and handshakes, everyone remained cautious. After all, years of violence, distrust, and vengefulness between Israel and Jordan could not be forgotten so easily. When negotiators drew up the terms for a treaty months earlier, it was clear there would be no political concessions on either side without seriously addressing the water allocation issue. Following the Six-Day War, Israel had started pumping 90% of the upstream flow, leaving Jordan to dry. Unfortunately, playing fair now no longer mattered as much as it did before – inevitably, the total water demand between Israel and Jordan had grown beyond what the entire Jordan River system could supply.

The rising demand for agricultural irrigation, coupled with a steep population growth rate had sunk their water budgets into red alert. Even today, US Aid expects Jordan's deficit to increase sharply by 297 to 408 million cubic meters (MCM) per year.[11] And, equally, Greenpeace suspects Israel will be 720 to 900 MCM short of their demand by 2010, taking into account the negative effects of climate change, such as less precipitation, higher evaporation, and more salination of groundwater.[12] These horrifying statistics were not available to the negotiators in 1994, but undoubtedly they would have seen the Dead Sea shrinking at a rate of three feet per year as a result of their competitive over-pumping.[13] The signs were clear: cooperate now or bear the consequences later. And so, in Annexes II and IV of the peace treaty, Israel and Jordan committed to "increasing water supplies and improving water use efficiency, within the context of bilateral, regional or international cooperation."[14] As specified by the rest of the articles, they would jointly plan construction of a dam along the Yarmouk River, manage groundwater resources of Emek Ha'arava, promise one another equitable water allocation, and even install a Joint Water Committee to protect the river system from contamination and illegal withdrawals. The provisions also formally reestablished the Jordan River as the Israeli-Jordanian border.

Despite Syria's dismissal of the event and Hezbollah's reactionary mortar attack on northern Galilee settlements that same day, the treaty was well received. At the signing ceremony at Wadi Araba in October, King Hussein spoke to an audience of foreign delegates:

> *Behind us here you see Eilat and Aqaba, the way we have lived over the years, in such close proximity – unable to meet, to visit each other, to develop this beautiful part of the world. No more – as we look into the future beyond this point, with determination, with hope, with commitment. We survived the hard times. Let our people beyond this point in time enjoy the good times.*[15]

And at the same presentation, Prime Minister Rabin explained what he saw:

> *From this podium, I look around and I see the Arava. Along the horizon, from the Jordanian side and the Israeli side, I see only a desert. There is almost no life here. There is no water, no well, and not a spring – only minefields. Such were the relations between Israel and Jordan during the last 47 years: a desert. Not one green leaf, no trees, not even a single flower… For nearly two generations, desolation pervaded the heart of our two peoples. The time has now come not merely to dream of a better future – but to realize it.*[16]

King Hussein and Prime Minister Rabin were each describing the same thing – a land and its people, tortured and divided over half a century of war. They did not explicitly mention water rights in either of their speeches, nor did they speak of the Jordan River.

But behind their careful words, they knew very well the effect water plays in peacemaking. The same surface tension that will pull nations apart can also be a force of desperate cooperation when conditions worsen – equally, the Jordan River can be a weapon of war or a penman of peace. And somehow, in spite of all their past conflicts, Israel and Jordan had at last come to agreeable terms. In an unlikely form, deliverance had arrived.

tism was actually the first one to occur since 1967, we may never know. But, to be certain, ever since the 1994 treaty, the Jordan River has increased enormously in popularity, and it now attracts hundreds of thousands of tourists each year.[18] Although the exact location of Jesus' baptism is debated, Christian pilgrims travel from all over the world to be close to the original site. Many choose to visit Yardenit, the most developed and scenic of all baptism sites,

Figure 4 *This 1902 sketch by Silas Xavier Floyd is characteristic of Christian traditions. Presumably, the scene here depicts John the Baptist baptizing Jesus in the Jordan River, as an audience stands by on the river banks. The lush and majestic landscape is probably exaggerated, but it also suggests that people have long admired the river's presence.*

Source: The University of North Carolina

Don't Drink the Holy Water

Four years later in 1998, on the fourth Sunday in August, young Chiara Buschittari's mother bent down to her knees in dirt, slowly, cradling her baby softly next to a brown stream. In the distance, tall banana trees and yellow tags "could be clearly seen sealing off the west bank of the river, where once a year, on the last day of October, the Christians, led by the Franciscans, are allowed to visit by the Isreali army."[17] The effects of the Six-Day War had not yet disappeared in landscape or in memory. Nor had it disappeared from the water – but, for the first time in 31 years, the Jordan River had returned to its former state: a place of baptism. Whether or not this particular baptism was located along the Israeli bank just below the Sea of Galilee. Still, Jordanians like to claim they have found the true "Bethany Beyond the Jordan" baptism site, nearby Wadi el-Kharrar on the east bank.[19] This is where Chiara was baptized. But for Israelis and Palestinians, Qasr Al Yahud ("The Jewish Palace") is the real thing. Unfortunately, it's also inaccessible – though only miles from Wadi el-Kharrar and the Dead Sea, Qasr Al Yahud is located along the west bank inside an occupied Israeli military zone.[20] And, consequently, the earth surrounding it is baked with land mines and scattered with more yellow warning tags. But for those who visit the river, the experience is often truly unforgettable. Imagine it for yourself:

the soft breeze rushing over your body like holy water, the pleasant abundance of green eucalyptus trees and date palms, and the magical, shear spiritual power of... raw sewage?

Just kilometers downstream from the crowd of unaware, white-robed pilgrims, a carrion perfume hovers in the air. Here, the Alumot Dam divides the Yardenit baptism site from the Batania Wastewater Treatment Plant outflow like a radiation shield. Below this, untreated and partially treated sewage, saline water, and fish pond effluent all flow from large drainage pipes into a mutated riverbed.[21] Could the same river, whose name and very being epitomizes the holiest of holy, the most sacred of all tradition, hope, and spirituality for some believers... could this same river really also be so grossly neglected that raw sewage pours freely from its veins? As if from Dante's Inferno, the Jordan now slowly descends into the River Styx. To borrow the stifled words of journalist Michele Chabin: "The stench is choking."[22]

> *2 Kings 2:21*
> *And he went forth unto the spring of the waters, and cast the salt in there, and said, Thus saith the LORD, I have healed these waters; there shall not be from thence any more death or barren land.*

Do Not Feed the Leptospira

So what exactly happened here? While the Israel-Jordan treaty of 1994 seemed to patch up political tears between the two countries, the river was apparently left out of the negotiations. To make matters worse, the established Joint Water Committee, which seemed like a promising solution thirteen years ago, has done little to regulate wastewater discharge into the Lower Jordan River. In fact, because Israel is developed and Jordan is not, different water management priorities arise from different standards of living.[23] Israeli, Jordanian, and Palestinian environmentalists all agree, without doubt, the river is infected. Gidon Bromberg is one of these, the Israeli head of Friends of the Earth Middle East (FoEME), a tri-national environmental NGO dedicated to addressing sustainable development and peace throughout the region. He observes, "Being baptized in the water below the dam – something that takes place on the Jordanian side of the river – cannot be too spiritually uplifting."[24] Was Chiara baptized in sewage?

Fifty years ago, the Jordan River had a total flow rate of about 1.3 billion cubic meters (BCM) per year into the Dead Sea.[25] Somewhere along the way, that same flow has dwindled to *100 million* cubic meters per year. Where did it all go? Undoubtedly, much of the river's water now travels primarily through the National Water Carrier and the King Abdullah Canal to hydrate agricultural fields in Israel and Jordan. Other water waits in storage, perhaps trapped behind one of Syria's twenty-seven small impoundment dams along the upper Yarmouk (most of which were built before 1988 but still continue to appear).[26] Just as Greenpeace and US Aid projected, this disturbing downward trend shows no signs of slowing. In 2003, after sorting through dusty design plans, Jordan and Syria revived their construction proposals for the Maqarin Dam, which alone will have a capacity to store 80 MCM along the Yarmouk River.[27] The long-awaited dam is scheduled to begin operation this year, just in time for the forty-year anniversary of the Six Day's War. Given the region's arid conditions and growing water demands, it is surprising these countries let any drop of water escape at all. Bromberg adds, "With Israel, Jordan, and Syria, each grabbing as much clean water as they can, it is ironically the sewage that is keeping the river alive today."[28]

But sewage alone cannot tell the full story: the Jordan Valley river system suffers also from agricultural runoff and contaminated ground water seepage. A group of researchers from the Technion Israel Institute of Technology collected water samples in 2004 along the Lower Jordan River and the Yarmouk River, in hopes to quantify the effect of shallow subsurface water on the observed chemical changes in the river's stream.[29] What they found was startlingly unsurprising – because of the Jordan River's unnatu-

rally low surface water flow rate, the river's chemistry is significantly impacted by groundwater. Just within twelve miles south of the Sea of Galilee and the rotten Alumot Dam, the team's measurements picked up decreasing concentrations of chloride, calcium, and sodium (naturally present in the water), paired with increasing concentrations of sulfate and magnesium (found in plant fertilizers). On average, their data revealed 300 mg/L of sulfate in the Jordan River and over twice that amount for agricultural drainage sites and parts of the Yarmouk River.[30] In spite of "decreasing" chloride concentrations, the river reported around 1400 mg/L of chloride.[b] Of course, while these concentration levels pose little health risk, they are definitely high enough to taste… that is, if anyone ever felt so inclined to taste a soup of waste effluent and farm runoff.

The numbers also suggest that other contaminants might be present, including small organisms and trace chemicals that might be difficult to detect but pack a punch to the average immune system. In fact, in June 2002, seven out 27 troops from the Israeli Defensive Force contracted leptospirosis after performing a series of weekly training exercises in the Jordan River, involving near-total submersion.[31] Baptisms in this area are also a health hazard: according to Gidon Bromberg, "You're likely to come out with a rash on your head."[32] The entire region is exhibiting signs of detriment. And it runs in the family. Ten years ago, the Zarqa River tributary was polluted beyond the point of access and use.[33] Due to reduced river flow and evaporation, over-pumping and mineral extraction, one third of the Dead Sea has disappeared. Thanks to the 1951 All Israel Plan, Lake Hula shared a similar dry fate and was drained completely until 1993, when Israel finally acknowledged it had actually spent seven years engineering itself a large, eroding dust bowl.[34] Turning points like these are crucial to watch in the evolution of the Jordan River. Recently, with the Hula Restoration Project underway and a Red Sea-Dead Sea water conveyance system in discussion, it seems as though sustainable practices are catching on.

b The United States EPA's guidelines for sulfate and chloride in drinking water are 250 mg/L for each.

Crossing the Jordan (For Better or Worse)

The Old Testament story of Joshua and the Israelites miraculously crossing the parted Jordan waters is often retold in Christian tradition. A curious mind might wonder: will people one day be able to walk across the river again? Perhaps so… but we would hardly need divine help. If current population trends continue, what we know today as the Jordan River may soon be no more than a dirty creek bed. There is also, incidentally, a glimmer of hope. After all, even

Table 1 | *Israel's Estimated Water Budget*

Source of Water	Price ($/m^3 water)	Current Capacity (MCM/year)	Drinking	Irrigation
Sea of Galilee (Lake Kinneret)	n/a	600	x	x
Lake Hula	n/a	100		x
Yarmouk River	n/a	100	x	x
Ground Water Wells	n/a	1000	x	x
Surface Flood Runoff	n/a	60		x
Imported Water from Turkey	0.8	50	x	x
Recycled Waste Water	0.35	300		x
Desalinated Brackish Water	0.33 – 0.42	50		x
Desalinated Seawater	0.52 – 0.55	4		x

Sources: The Washington Institute of Near East Policy, Mekorot Water Company, and the Jewish Virtual Library

the most soiled of puddles can still reflect the sun.

In the 21st century, governments and universities, researchers, companies, and NGOs from all over the world have assembled to craft new sustainable water management plans for this area. One such plan named IWRM-SMART is comprised of twenty one different players (including Jordan's Ministry of Water and Irrigation, the Palestinian Hydrology Group, and Mekorot Water Co., Israel's largest water distributor and owner of the National Water Carrier).[35] The consortium held their first official meeting in March 2007 to address management strategies for the Jordan River. And, although it may still be too early to tell how the young group will fare, it is by far the most extensive and ambitious collaboration of any Jordan River project to date. At this point, their website remains undeveloped and rather vague, but their objectives suggest that innovative water technologies will be the focal point of their future efforts. Conservative drip irrigation systems have long been used in Israel to minimize its agricultural water demand. Additionally, desalination treatments and waste water recycling plants provide cost-effective alternatives to freshwater irrigation (see Table 1), but they do not yet consistently output a water quality high enough for dinking.[36]

If these technologies were enough to save the river on their own, this essay would be quickly nearing a triumphant, cinematic ending. It may be true that Israel pioneered modern drip irrigation fifty years ago and that, while the region has few freshwater resources, it is also surrounded by vast bodies of salt water just waiting to be desalinized. And, without a doubt, new drip irrigation and desalination techniques do have the potential to help alleviate the Middle East's water crisis and restore life to the Jordan River. But technology by itself has never created peace… and what the Jordan River really needs is peace. In truth, without lasting peace between people, technology only tends to accentuate their disparities and conflicts.

If the Jordan River ever had a champion of peace, it would be Gidon Bromberg. Bromberg's quotes have been scattered all throughout these last few pages for two reasons: firstly, they are incredibly insightful; but, more than that, they are in fact everywhere – in journals, newspapers, and video clips around the world. And Bromberg himself is everywhere, speaking on behalf of the river and its people. At the Wilson Center in Washington, D.C., he has met with mayors from Jordan, Israel, and the Palestinian Territories.[37] By the banks of the Jordan River, he has kayaked with these mayors, while they joined hands and held their respective country's flag in the air, floating leisurely beneath the old stone bridge at Gesher.[38] In honor of his tireless efforts to broaden understanding in the region, Yale University named Bromberg one of eighteen Yale World Fellows for 2007.[39] Of course, he does not work alone. Instead, as a co-director of FoEME, he has led a rare group of dedicated environmental activists to revive the river with the help of communities and local governments.

Table 2 | *Role of Agricullture in Gross Domestic Product*

Country	*(1) % Water Spent on Irrigation*	*(2) % GDP from Agriculture*	*Ratio (2)/(1)*
Israel	60	2.6	**0.043**
Jordan	80	3.6	**0.045**
United States	65	0.9	**0.014**

Source: CIA World Factbook, U.S. Geological Survey

The Question is Posed

The ultimate question came to light in 2004 during the middle of an interview with Bromberg: "Do you think there's enough water in this region for everybody?"[40] Although the transcript does not narrate the conversation specifically, Bromberg's reply suggests he had begun his answer before allowing the question to finish: "Oh yes, definitely. There's definitely enough." How could he be so sure? Had he not heard of the US Aid or Greenpeace water deficit projections? Are the populations of the Middle East not rising? Is climate change not as real as scientists say? Actually, Bromberg was well aware of the complicated and dire situation. But still he sat there, oddly, arguing that water scarcity is not a problem in the Middle East.

The true issue, he argues, is water allocation. 60% of Israel's freshwater supply goes to irrigation, even though agriculture provides for only 2.6% of its GDP (Gross Domestic Product).[41] Matters in Jordan are just as extreme (see Table 2). And interestingly enough, if one were to look up the same statistics for the United States, the gap between water spent on irrigation and its contribution to the economy is actually even more strikig…However, at least for now, the United States can afford the luxury of growing most of its own food. The Middle East, on the other hand, is extremely arid with relatively few available fresh water resources – to survive in the long run, it must have sustainable priorities. If Bromberg were here talking with us, he would interrupt again:

> *We're growing bananas! Israel and Jordan, in the Jordan Valley, we're both growing bananas, a crop with the most ridiculously high water consumption. We could be importing bananas from Sudan, which is not far away, at half the price, if economic indicators were much more realistic, if farmers were paying the true cost of water. They're not. That's another policy issue that we deal with.*[42]

At this part of the interview, Bromberg hints at a broader water allocation problem that exists in the region today. Surprisingly, it has little to do with transboundary allocations, which were the primary concern in 1994. In reality, water is valuable. Yet, even though they may invest in the most advanced water conservation technologies, Israel and Jordan consistently use the water in relatively unimportant and unproductive ways. Presently, agricultural water is scarce but otherwise inexpensive, leaving farmers with little or no incentive to save it. But simply conserving water is not enough – the region must scale down its agricultural sector entirely, growing only those crops that are crucial to its food supply and difficult to import securely and economically.

With the extra water and other resources gained by offsetting their agriculture production, Israel and Jordan would suddenly have the power to reinvest in their economies. As previously discussed, the area is ripe for tourism, both religious and recreational. Yet, at the same time, creating an unrestrained base for mass tourism could easily have negative environmental impacts on the river. No doubt, when hotels begin to populate along the banks, Westerners are sure to follow, their luggage at hand and sunglasses fully loaded. They scatter like movie stars, drinking, and tanning along any available bed of fresh water. Israel and Jordan should avoid this sort of fate at all costs. Accordingly, they must approach tourism from a perspective of sustainability. Where are hotel clusters best suited? How much tourism is too much? If designed correctly, sustainable tourism can spread an awareness of the river's environmental problems. It can encourage cooperation between the people of Israel and Jordan. Particularly, it can foster large amounts of revenue for both countries, which, in turn, can go back into their economies to develop further leading-edge desalination or drip irrigation technologies.

To work towards this goal, FoEME has helped the Jordan Ministry of Tourism and Antiquities submit a proposal to the UNESCO[c] World Heritage Center.[43] The baptismal pool nearby Wadi el-Kharrar is currently listed as a tentative World Heritage site,

c United Nations Educational, Scientific, and Cultural Organization

and, if accepted, would attract thousands of additional visitors to the Jordan River and the Dead Sea each year. To delight and educate these travelers when they arrive, FoEME has also proposed the establishment of Peace Parks along the river, including one at the current "Old Bridges" tourist site.[44] A Peace Park, as envisioned by the World Conservation Union (IUCN), intentionally overlaps boundaries between multiple countries and breaks down their political borders. Here, people and animals are allowed to come and go freely within the area – specifically, visitors can watch migratory birds, hike, bike, and follow guided tours, which blend together elements of history, religion, and nature.

Lastly, it is important that Israel, Jordan, and – let us not forget – Syria and Lebanon all have their rightful ownership to the water. But they are not nearly its only stakeholders. Christians and Muslims all over the world have a place in the river, and many of them would all but crusade to save it from extinction. Apparently, the news has simply not spread enough yet among the world's churches and mosques. Perhaps it will, in time, thanks to Bromberg and the Friends of the Earth Middle East.

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A New Prophecy

After our journey down, around, and through the Jordan River, we are like the waters. And, if so, we too must inevitably return to the original question: is the River Jordan really dammed to hell? Well, not necessarily. Possibly, as we have learned, it is only dammed to purgatory. After all, the Jordan River had been flowing full for thousands upon millions of years until now. In its lifetime, it has seen continents collide, men stand upright, caravans roll by carrying gold and silver… it has seen face of God, the uncertainty of man, and the blood he sheds. It was around for the Romans when they needed a bridge. It was around for Jesus when he needed a priest. It was around for Jewish Zionists when they needed a war of independence. And, now, the Jordan River system makes life possible for millions of people, all who live in Tel-Aviv, Jericho, Jerusalem, and Amman, and in the other towns scattered throughout the valley region.

Nevertheless, the Jordan River is not what it used to be. Its waters are overdrawn and polluted by dams and pipelines. According to water deficit trendlines, the crisis is immediate and will only worsen in time. The unanswerable matter is: when the situation becomes too desperate, how will Israel react? How will Jordan react? How will the river react?

To say that the stability of the Middle East depends on the future of the Jordan River is overwhelming. But, in some ways, it is also probably true, which then means that nearly every major country in the world actually has a small stake in the wellbeing of the Jordan River. The United States has expressed its concerns, writing letters to the Jordan government from Congress and responding to peace talk requests from Jordan's King Abdullah.[45] In any case, it is apparent that the river's future depends upon support from the riparians, the international community, and all in faith who claim some part of the Jordan River. And, as we have seen from Friends of the Earth and other recently arising interest groups, there is hope in numbers…

> *Job 40:23*
> *When the river rages, he is not alarmed; he is secure, though the Jordan should surge against his mouth.*

One by one, drops of salty mist awake and climb from their sea bed. Taken by the sun, they are headed for the skies, though they do not know where, how, or why. To say they know anything at all is a stretch of imagination. But if they did know something, they would know this: I am moving! Indeed, they are moving. They are all moving as vapor to become the white clouds above. They rise higher still, as if scaling the world's largest roller coaster ride. The fall will come, but do they know it? As they continue to soar, it becomes cold, and they begin to huddle together. There is warmth in numbers. The sky be-

comes a hazy white, and those of them that can think wonder if they have at last seen death's color. The cold overwhelms them, pushes them together, and, in a final wisp and inward breath, it pushes them off. And then it snows.

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Photosynthetic Pigments of Plants in a Tropical Cloud Forest: An Example of Low Productivity and Specialized Acclimation

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Abstract

Based on the character of their natural light environments, the photosynthetic pigments of canopy and forest floor plants of a tropical cloud forest were analyzed and compared. It was found that canopy and forest floor plants possess equivalent concentrations of photosynthetic pigments per mass of leaf tissue ($\bar{x}$ = 0.21± 0.09 mg/g and 0.22 ± 0.11 mg/g, respectively). From this it can be interpreted that plants from these two microhabitats invest the same energy in major pigments for photosynthesis. However, differences in leaf morphology allow canopy plants to contain a higher concentration of photosynthetic pigments per

area ($\bar{x}$ = 0.0079 ± 0.0026 mg/cm²) than forest floor plants ($\bar{x}$ = 0.0059 ± 0.0019 mg/cm²). Although the forest floor ($\bar{x}$ = 0.98 ± 0.26) had a much lower ratio of chlorophyll a to chlorophyll b (chl a/b) than the canopy ($\bar{x}$ =1.63 ± 0.57), both cloud forest plant forms have exceptionally low chl a/b compared to plants of other environments. Since low chl a/b correlates to low energy production, the cloud forest appears to have relatively reduced primary productivity. Both the canopy and forest floor plants contain similarly high proportionalities of carotenoids to total chlorophylls (car/chl) ($\bar{x}$ = 0.48 ± 0.10 and $\bar{x}$ = 0.49 ± 0.13, respectively). Based on the disparities in their light environments, though, the canopy would be using the additional carotenoids for photoprotection whereas the carotenoids of the forest floor plants would be functioning as antenna pigments for photosynthesis. Because the plants of the tropical cloud forests display low productivity and acclimations specific to their existing environment, this ecosystem may be exceptionally vulnerable to future anthropological disturbances.

Introduction

A tropical forest has two contrasting strata, one characterized by the tall, closed canopy of climax trees and the other a forest floor of small shade-tolerant trees and shrubs (Rundel and Gibson, 1996). Since sunlight can be the most important, and often the most limiting, resource to plants in the tropical forest, it is not surprising that close connections have been found between the light conditions the physiology of plants in these distinctive forest layers. Solar radiation, which is virtually unobstructed in reaching the top of many tropical forests, has irradiance levels upon the canopy that often exceed 1000 µmol m^{-2} s^{-1} of sunlight (Chazdon and Fetcher, 1984). Although light is a valuable resource for plants, periods of high intensities of light can sometimes be destructive. This damage lowers the efficiency of photosynthesis, a process known as photoinhibition. However, cloud formations greatly effect the diffusion of light, reducing the midday sunlight that reaches the canopy up to 75% (Chazdon et al., 1996). Cloud forests are distinct from other forest due to a perpetual foggy mist that hovers above and within the forest. Measurements of the tropical cloud forest canopy in Monteverde, Costa Rica reveal that cloud formations cause irradiance levels to be reduced to 400 – 500 µmol m^{-2} s^{-1} of sunlight (Lawton, 1990).

In contrast to the canopy, only about 1% of sunlight effectively penetrates to the forest floor level of most tropical forests, producing diffuse background irradiation of approximately 10 µmol m-2 s-1 of light

Figure 1 *Photograph of afternoon low cloud cover above and within the tropical cloud forest near the Estación Biológica in Monteverde, Costa Rica*

Photograph of afternoon low cloud cover above and within the tropical cloud forest near the Estación Biológica in Monteverde, Cost Rica

(Chazdon and Fetcher, 1984; Chazdon et al., 1996). However, the forest floor of a cloud forest receives slightly more diffuse sunlight than that of a typical forest floor due to the increased scattering of light from the clouds (Lawton, 1990; Endler, 1993). Brief intervals of direct sunlight, termed sunflecks, are very important for light accessibility in the low-light environment of the majority of forest floor plants. For the plants that receive these sunflecks, about 60% of daily light is absorbed during these short periods (Anderson et al., 1988). However, sunflecks are quite rare in cloud forests due to the midday fog above the canopy and forest floor. The fluctuations of sunlight observed on the forest floor of a typical forest are not as common for a tropical cloud forest. Thus over the entire day, the amount of light reaching the cloud forest floor is actually quite low (Lawton, 1990).

The original purpose of this experiment was to compare the photosynthetic adaptations of the canopy and forest floor plants. These adaptations were compared by analyzing the overall concentrations and the balance of photosynthetic pigments within the plants. However, since the photosynthetic pigments of cloud forest plants have not been examined before, the comparison of the results between the cloud forest and previously published data for plants in other ecosystems became much more insightful. Based upon the sizeable contrasts between cloud forest plants and plants found in other environments, the consequences of regular cloud formations on the photosynthetic abilities of plants became the primary focus of this investigation.

Materials and Methods

This study was conducted in the Tropical Cloud Forests of Monteverde, Costa Rica. Samples were collected at the end of the rainy season, during the month of November, 2006. During this time, the weather of this cloud forest had a somewhat regular daily pattern. The mornings (0700 to 1100) were usually characterized by rather clear, blue skies. Low, heavy cloud formations generally saturated the sky during the middle of the day (1100 to 1400). A few hours of rainfall typically followed the midday clouds (1400 to 1600). The evenings were usually characterized by fairly clear skies with light to medium scattering of overhead clouds (1600 to 1900). All leaf samples were collected during the clear skies of midmorning. The 20 canopy samples were collected from an aerial canopy tram in the secondary forest of Natural Wonders using pole-clippers. The 20 forest floor samples were collected from the forest floor of a closed canopy mixed primary and secondary forest near the Estación Biológica using a pocketknife. All leaf samples were obtained from the crown of the plants. All samples were subsequently placed in a large plastic bag. To reduce damage to the light absorbing pigments, this plastic was then placed in an ice bath within a double-bagged, black, plastic garbage bag. To further control pigment damage, the leaf samples were analyzed in the laboratory the day of extraction. Leaves from each individual plant were measured and cut to an area of 50 cm^2 using stencils and a single-edged razor blade. The 50 cm^2 of leaf were then subsequently shredded and reduced to very fine leaf fragments using the single-edged razor blade. The mass of the 50 cm^2, now in fine leaf fragments, was recorded using a FischerScientific T top loading balance. Photosynthetic pigments were extracted from the leaf fragments using 7 ml of 85% acetone solution. This solution was sustained at a pH of 6.5 with 2 ml of phosphate buffer (pH 6.5). The photosynthetic pigments were allowed to precipitate in the acetone solution for 15 min. During this 15 min period, the solutions were shaken for a period of 30 s every 5 min in order to increase the interactions of leaf fragments with the acetone. The mixture was then centrifuged at 4000 rpm with a Premiere XC-1000 centrifuge to separate and pellet the leaf fragments from the acetone-pigment solution. The purified acetone-pigment solution was then decanted into a graduated cylinder. Two ml of the acetone-pigment solution were subsequently added to 8 ml of 85% acetone in a cuvet. Using a Sequoia-Turner Model 340 spectrophotometer, absorption readings of the diluted acetone-pigment solution were then

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taken at light wavelengths of 663, 646, and 470 nm. The concentrations of pigments, *per area* and *per mass*, were determined using equations derived from Lichtenthaler and Welbur (1983). Using the pigment concentrations, ratios of chlorophyll *a* to chlorophyll *b* (chl *a*/*b*) and carotenoids to total chl (car/chl) were determined.

Results

Descriptions. — Overall, chlorophyll constituted the majority (68.3 ± 0.9%) of the photosynthetic pigments extracted from the plants. Specifically, chlorophyll *a* was the most abundant pigment, representing 37.7 ± 0.5% of the measured pigments. Chlorophyll *b*, having the lowest amount, comprised only 30.1 ± 0.4% while carotenoids generated 31.6 ± 0.4% of the measured pigments.

Concentration Analysis. — The concentrations of photosynthetic pigments *per mass* of leaf tissue (Fig. 1) were not significantly different between canopy ($\bar{x}$ = 0.30 ± 0.13 mg/g) and forest floor plants ($\bar{x}$ = 0.32 ± 0.17 mg/g); (t-test, t = 0.35, df = 38.44, P < 0.05). A large range was observed in total pigments per mass from 0.72 to 0.10 mg/g, both for forest floor plants. However, based on *area*, concentrations of pigments (Fig. 2) were significantly

Figure 2 *Comparison of each photosynthetic pigment concentration ($\bar{x}$ ± sd) per mass of leaf tissue in canopy and forest floor.*

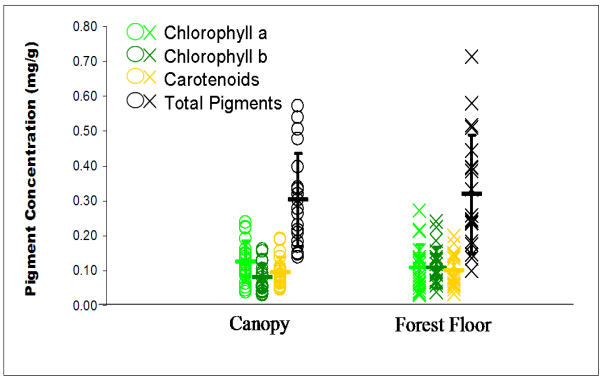
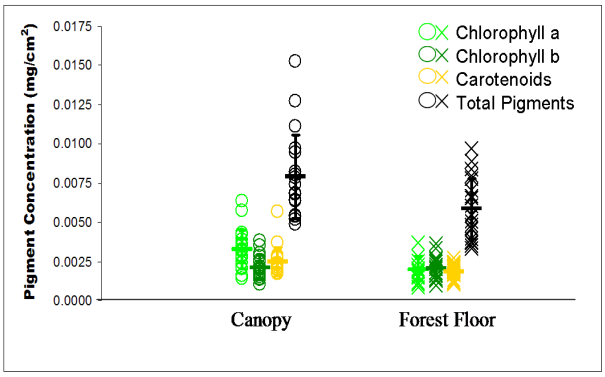


Figure 3 *Comparison of each photosynthetic pigment concentration ($\bar{x}$ ± sd) per area of leaf tissue in canopy and forest floor.*



higher in canopy plants ($\bar{x}$ = 0.0079 ± 0.0026 mg/cm²) than forest floor plants ($\bar{x}$ = 0.0059 ± 0.0019 mg/cm²); (t-test, t = 2.79, df = 36.89, P < 0.05). The range for total pigments per area ranged from 0.0034 (forest floor) to 0.0153 mg/cm² (canopy). The pigment concentrations are not absolute since the methods here attempted to suspend most, but not *all*, pigment molecules.

Ratios. —The chl a/b was significantly lower (Fig. 3) in forest floor plants ($\bar{x}$ = 0.98 ± 0.26) in relation to canopy plants ($\bar{x}$ = 1.63 ± 0.57); (t-test, t = 4.63, df = 38.00, P < 0.05). For plants of the tropical cloud forest, chl a/b ranged from 0.61 (forest floor) to 3.43 (canopy). The canopy ($\bar{x}$ = 0.48 ± 0.10) and forest floor ($\bar{x}$ = 0.49 ± 0.13) demonstrated no significant difference in the ratio of car/chl (Fig. 4); (t-test, t = 0.31, df = 40.14, P < 0.05). The range for car/chl was 0.29 (canopy) to 0.90 (forest floor).

Discussion

Differences in both photosynthetic pigment concentrations and ratios suggest that canopy and forest floor plants within the cloud forest employ different techniques for light absorption in their respective light environments. Since the measure of photosynthetic pigment concentrations *per mass*

Figure 4 *Comparison of chlorophyll a to b ratio ($\bar{x}$ ± sd) in canopy and forest floor.*

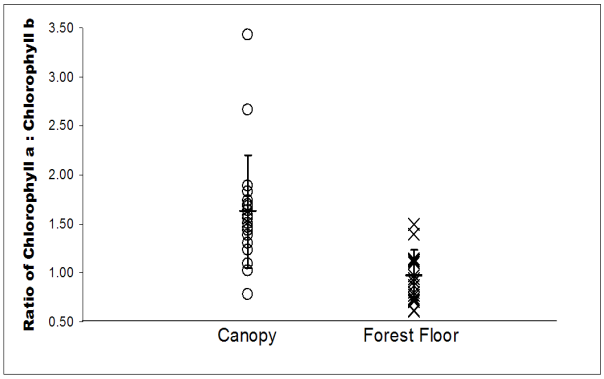
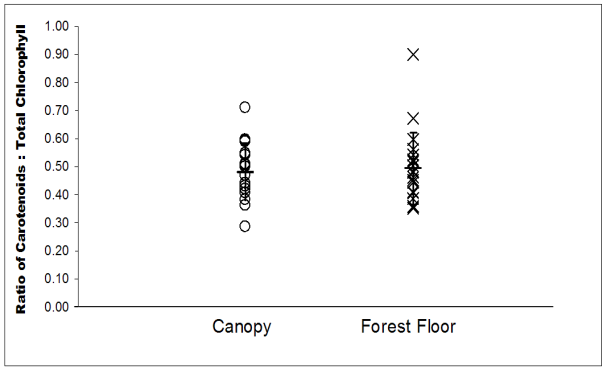


Figure 5 *Comparison of carotenoids to total chlorophyll ratio ($\bar{x}$ ± sd) in canopy and forest floor.*



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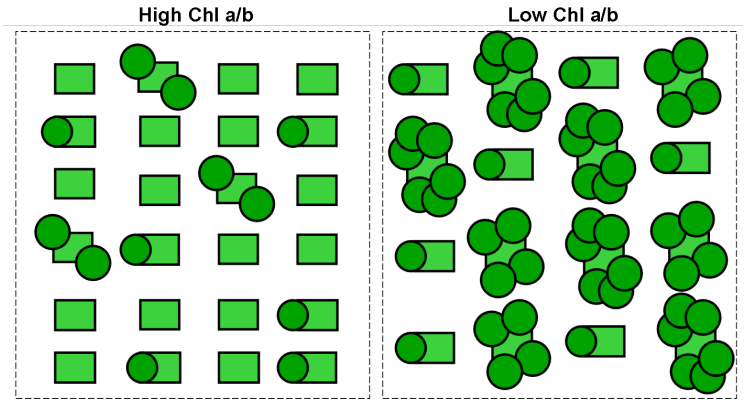
determines the amount pigments in relation to other elements of the leaf, this assessment can be used to compare the expenditure of energy and resources on photosynthesis. Because both canopy and forest floor plants have similar pigment content *per mass* of leaf (Fig. 1), these two growth forms appear to give similar investments for photosynthesis. Canopy plants, however, demonstrated an increased level of photosynthetic pigments *per area* when compared to forest floor plants (Fig. 2). The basis of this result can be ascribed to differences between the physical characteristics of leaves in canopy and forest floor plants. Since canopy leaves are generally thicker than forest floor leaves (unpublished data), the larger leaf thickness allows more photosynthetic units to be present in a given area (Boardman 1977; Rundel and Gibson, 1996). As not all light may be captured by the top layer of cells within the leaf, increased leaf thickness would enable these canopy plants to absorb additional light incident upon it. Because very little light actually penetrates to the forest floor, thicker leaves are not essential for the plants found in this microenvironment. Other adaptations may be more economical for the forest floor.

Ratios of individual pigments within a leaf can be a reliable indicator to determine the photosynthetic adaptation of a plant to its given light environment. With the analyses of the photosynthetic pigments of many plants, important correlations between chlorophyll ratios and photosynthetic capacities have been shown. Overall energy production is tightly associated with the chl a/b. Plants with low chl a/b display a low capacity for energy production while plants with a high chl a/b demonstrate a relatively greater capacity (Anderson et al., 1988). Therefore, the cloud forest canopy trees, having a higher chl a/b than forest floor plants (Fig. 3), would likely be more productive than the forest floor plants. This is evident in the much greater biomass of larger canopy tress such as the more abundant foliage personally observed in the top layer of the cloud forest. The relationship between energy production and chl a/b is due to the specifics of the light absorbing and converting structures of the leaf. Those structures which actually convert light into usable energy, called the reaction centers, contain only chlorophyll *a* (Ben-shem et al., 2003; Ferreira et al., 2004). Chlorophyll *b* is only located in the antenna structures, called light-harvesting complexes, which assist the reaction centers in absorbing light (Ben-shem et al., 2003; Ferreira et al., 2004). It has been shown that plants are able to manipulate the relative amounts of reaction centers and light-harvesting complexes in order to acclimate to their light environment (Peter and Thornber, 1991; Boekema et al., 1999; Ballottari et al., 2007). A high chl a/b would indicate that there are many reaction centers, while a leaf with a low chl a/b would suggest relatively fewer reaction centers and more light-harvesting complexes (Fig. 5). Those plants with many reaction centers (high chl a/b) are able to absorb the available sunlight and very quickly transform it into usable energy. On the other hand, plants with many light-harvesting complexes associated with very few reaction centers (low chl a/b) sacrifice the capacity for photosynthesis in order to amplify the amount of available light that they are able to absorb. Available light appears to be an important factor in how a plant distributes the chlorophyll within its leaves. Plants grown where light is readily accessible allocate most of their chlorophyll pigments for reaction centers whereas plants that are grown in low light environments produce many light-harvesting complexes for their chlorophyll (Anderson et al., 1988; Chow et al., 1990; Bailey et al., 2001).

Comparing against plants of other habitats, the chl a/b of cloud forest leaves is extraordinarily low. Usual numbers for the ratio of chl a/b for plants with leaves in direct sunlight or high light usually vary from 2.5 to greater than 3 (Leong and Anderson, 1984; Anderson et al. 1988; Königer et al., 1995; Murchie and Horton, 1998; Goncalves et al. 2001). In contrast, plants growing under natural shade or low light generally display a chl a/b ranging from about 1.75 to 3 (Anderson et al., 1973; Leong and Anderson, 1984; Anderson et al. 1988; Königer et al., 1995; Murchie and Horton, 1998; Chow et al., 1990;

Figure 6 — *Simplified top view of reaction centers (■) and associated light-harvesting complexes (●). **Left Side.** Plants with a high chl a/b show increased numbers of reaction centers with a relatively small number light harvesting complexes. **Left Side.** Plants with a low chl a/b exhibit more light-harvesting complexes associated with comparatively fewer reactions centers.*



Goncalves et al. 2001). The lowest ratio that could be found for a plant was 1.65 for an Australian shade-adapted species (Chow et al., 1990). Compared to the well established levels of other ecosystems, the canopy and forest floor plants of the cloud forest have very large proportions of chlorophyll b, resulting in a rather low chl a/b. Although the large amounts of light-harvesting complexes would allow the tropical cloud forest plants to absorb a large range of incident light, the primary production capacities of the cloud forest are presumably quite low due to the relatively fewer reaction centers. Other experiments on the photosynthesis of plants in the tropical cloud forest also suggest a relatively low level of primary production (Letts and Mulligan, 2005). Measurements of other forest features such as litterfall and tree trunk growth furthermore demonstrate this low productivity in cloud forest plants (Bruijnzeel and Veneklaas, 1998; and references therein). Productivity of the plants within a forest is very important for the maintenance of that forest. Since many forest animals depend on plants for their food supply either directly or indirectly, forest plants lay the foundation for the food chain. An assortment of other organisms like the forest animals also depend on the plants of the forest for their microhabitats and shelter. Being that the production level of these plants is naturally quite low, even small disturbances to the tropical cloud forest may be extremely detrimental to the habitat.

Another correlation has been illustrated between chl a/b and the amount of light that can be used for photosynthesis. Those plants with low levels of chl a/b typically become saturated with light at very low levels (Boardman, 1977). Because of this, not much benefit would be gained by either the canopy or forest floor during times when intense sunlight is unimpeded to the leaves. In actuality, unobstructed light would most likely be harmful to these plants because photoinhibition occurs during those times in which photosynthesis is saturated. This is where carotenoids become important for the photosynthetic efficiency of a plant. Carotenoids, which can be used to absorb light for photosynthesis, also operate to absorb excess light that would otherwise be destructive to the photosynthetic elements of the leaf. Low-light conditions favor the former function

whereas the latter role is conducive in high-light environments (Frank et al., 1994). In nature, the car/chl is generally higher in plants more exposed to the sun because of its significance in protection from excessive light damage. In comparison to other forests, the canopy of the cloud forest has a rather elevated car/chl (Königer et al., 1995; Goncalves et al. 2001). Since cloud forest plants have relatively low saturation levels for photosynthesis and changes in cloud cover can cause tremendous fluctuations in available sunlight, additional carotenoids would be beneficial for photoprotection during times of intense sunlight. Additionally, these carotenoids could operate as antenna pigments for photosynthesis when the leaves are shaded by usual cloud cover. Even more notable is how remarkably greater the car/chl is in the plants of the cloud forest floor than other forest floors (Königer et al., 1995; Goncalves et al. 2001). As sunflecks, which are usually crucial for photosynthesis in forest floor plants, are uncommon under the typical cloud cover and forest canopy, other means of effective light absorption are necessary. Carotenoids, in addition to the antenna pigment chlorophyll b, would be very valuable to the forest floor in absorbing additional light for photosynthesis in the cloud forest. In actuality, the canopy and forest floor plants of the cloud forest had very similar car/chl to each other (Fig. 4), although the function of these pigments may be somewhat different. Since both plant types of the cloud forest appear to be especially adapted to the light conditions caused by the frequent fogs and mists, drastic changes in this cloud coverage may pose a serious threat to this environment. Novel light intensities would most likely be damaging to the leaves of these plants as they are acclimated to saturate at fairly low levels of available light.

The preservation of tropical cloud forests will be very important in maintaining these unique habitats since primary production is essential to the stability of these communities (Fretwell, 1985; and references therein). Due to its naturally low production rates, tropical cloud forests are particularly more sensitive to anthropogenic disturbances. Direct disturbances, for example the logging of trees, spread of agriculture, and expansion of human populations in these areas, must be reduced or discontinued in order to protect the cloud forests (Wheelwright, 2000). The minimization of indirect human disturbances on these ecosystems, such as climate change, is likely to be valuable as well. Relatively recent studies indicate the increased susceptibility of the tropical cloud forests to changing climatic patterns (Pounds et al., 1999; Pounds et al., 2006). As the magnitude in which human disturbances impact the environment is starting to be better understood, the conservation of tropical cloud forests is essential for protecting the plants and animals that inhabit this vulnerable ecosystem.

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Emma Bovary's Blind Beggar: Repressed Reality

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Despite his status as a relatively minor character in the novel, the blind beggar in Gustave Flaubert's Madame Bovary has intrigued many literary critics. D.L. Demorest, one of the first critics to assert his interpretation of the beggar, views the blind man as "l'incarnation de Némésis [incarnation of the Enemy]" (466). He is the presence that haunts Emma wherever she goes. She sees his grotesque face as she returns from her rendezvous with Léon, during her downfall and just prior to her death. She also hears his cacophonous song, the last sound she hears before she dies. Her last words proclaim the blind man. Thus, he is "un symbole de

la vie d'Emma et de sa fin [a symbol of Emma's life and her end]" (Demorest 468). Similarly, Albert Thibaudet contends that the blind beggar is "une figure de damnation [a figure of damnation]" (96), hovering over Emma's demise. He is the grimacing monster that menaces her during her travels to Rouen and reminds her of her adultery. When she gives him her last piece of silver, she is essentially giving her sinful and corrupt soul to him. She dies with an atrocious laugh, connected to the beggar's song that she hears. Likewise, Harry Levin argues that the blind beggar is a monster, a "memento mori" (265). For Levin, he symbolizes human frailty.

However, there are critics who see the blind beggar as representing reality, not pure evil. According to Sheila Bell, the beggar is a representation of the horrible realities in Emma's life, "more mundane and more horrific" (29). He is not a powerful figure tormenting sinners, but a vulnerable outcast. Murray Sachs also rejects the positions of Demorest, Thibaudet, and Levin. He claims that the beggar symbolizes the "ugly truths of life" (74), the reality that appears once Emma's romantic veneer strips away. Sachs attributes Demorest, Thibaudet, and Levin's views from their misreading the text. According to Sachs, they place excessive emphasis on the beggar's appearance at Emma's death. They exclude other scenes, for example, Emma's return from Rouen every Thursday. Thus, they only infer the supposedly omnipotent evil aspect of the beggar and ignore contexts where he is less powerful and more routine. To Sachs, the beggar is the "ugly and disturbing apparition" who regularly distresses Emma. His constant reappearances signal how reality creeps into Emma's imagination. Emma cannot prevent him from entering her life. The beggar also contrasts the "Babylon of pleasures and the one hundred and twenty thousand souls palpitating with passion," the Rouen that Emma imagines, with what the city actually is. Thus, the city is not the glamorous place Emma believes it is. Reality is far less beautiful than her imagination. Hence, the beggar "acts as a catalyst that precipitates the collapse of the last vestiges of her illusions and plunges her into a melancholy recognition of reality" (Sachs 75).

Although recognizing the views of both groups of critics, one can see that the blind beggar is more a portrayal of reality's truth, rather than an all-powerful symbol of sin and corruption. He is not a strong, forceful character, but quite weak and vulnerable. He is not immune to daily life's pettiness. In the text, he is an outcast and a victim to Homais' quackery and self-aggrandizement. While he appears at Emma's death and continually haunts her as she sinks into ruin, he is not an evil being intent on seizing her tarnished soul. He demonstrates the "determined flight from reality, followed by the inevitable descent back to the painful truth." The definition of reality is the harsh world of human frailty. Thus, the beggar does not symbolize damnation, but represents Emma's denial of reality and reality's brutality.

Throughout the novel, Emma allows fantasy to trump reality. She idealizes and longs for a romantic world, a "world of ambassadors trod over gleaming parquet floors" (Flaubert 75), that sharply contrasts with her present life. She fails to see things as they truly are. A wide disparity exists between the life she fantasizes and the life she actually lives. Her vivid imagination permits her to escape from her dull marriage to a mediocre country doctor, possessing "conversation…flat as a sidewalk" (Flaubert 60), and from the provincial town she calls home. It also causes her to commence illicit affairs with two men and to spend money until bankruptcy.

Throughout her sexual liaisons, she ignores the risk of sexually transmitted diseases. During the nineteenth century, those diseases, specifically syphilis and gonorrhea, were mostly known and discussed for prostitutes and other "immoral women" (Walkowitz 56). Nevertheless, a young married woman like Emma, especially someone having affairs with young bachelors who have made love to women before, faces the probability of acquiring an infection. Love is not something to place on a pedestal, but to proceed with using caution. In Madame Bovary, it transforms into a "hideous pathological condition spread by genital contact" (Donaldson-Evans 19). Every time she meets

Rodolphe or Léon, she flirts with the possibility for acquiring a debilitating illness. The beggar's scrofula highlights the venereal diseases Emma could contract. Ignoring her risks for disease and avoiding the beggar reveals her duplicity and desire for "shutting them off" (Freud 148) from her memory.

Similar to ignoring the chance of acquiring illnesses from her adulterous affairs, she ignores the negative consequences of dying. She considers a death from arsenic poisoning as a romantic method to escape her misery and repress reality. It would end the troubles which "loomed before her like an abyss" (Flaubert 292). However, the pain and suffering she endures as she dies is more than she initially anticipates. Hence, the reality of death is not beautiful, but ugly and shocking. Her "vomiting blood" (Flaubert 297) and her body "covered with brown patches" link her to the beggar. Both have transformed into weak individuals, powerless to cease their afflictions. Ironically, the beggar is not a powerful being coordinating Emma's looming demise and eternal punishment, but is vulnerable. He shows pain and wretchedness. His appearance at her death scene further serves to demonstrate how she cannot flee from anguish and harshness. While his presence can convey a menacing sense of damnation, the blind man as a menace, his real function is "uncovering the resistance…and acquainting" (Freud 155) Emma with the reality she does not recognize. For her, reality is the dullness and brutality of her provincial life, fraught with human weakness, entirely different from everything she idealizes. She is not the strong, forceful figure she imagines that her reading and affairs will allow her to become.

Furthermore, Emma's resistance to the truth of dying leads to how the beggar represents all that Emma represses. She refuses to see consequences. She adamantly holds firm to her imagination. According to Sigmund Freud, what an individual represses eventually resurfaces. Therefore, all that Emma has repressed during the novel floods her conscience as she faces the results of her actions. The beggar becomes "a constant accompaniment, a regularly reappearing figure" (Bell 29). For example, his song that she hears from her deathbed is a significant auditory image. It forces her out of the sensual and otherworldly trance she creates as she takes communion and kisses the crucifix and returns her to the real world. Therefore, the beggar overcomes Emma's "resistances due to repression" (Freud 148).

While Emma floats in her imaginary world, the beggar sinks in his poverty and disease. He is the weight that smashes all of her fantasies. He is grotesque, skin hanging "in shreds around the eyes" (Donaldson-Evans 17), to counteract the beauty Emma idealizes. He demonstrates how reality is hideous and imperfect. He shocks Emma to force her to reject her romantic illusions. His persistent presence explains that she cannot flee from contact with reality and symbolizes "that reality in all its raw and brutal truth" (Sachs 75). It will always find some way to burst into her life and destroy all of her dreams. Her dream world is fragile, no match for reality's awesome power. In addition, his scrofulous complexion signals the "awful specter of venereal disease" (Donaldson-Evans 17) that Emma could acquire as an adulteress. Her affairs will bring consequences that will significantly affect her and her family. Her actions will linger and haunt her for the rest of her life. The beggar shows how human error and selfishness are attributes of reality. He is not an absolute symbol of reality, but in P.M. Wetherill's view, reinforces the banality and meaninglessness of life (40). The beggar is, in the words of Mary Donaldson-Evans, the "physical representation of her degradation" (17).

Along with representing the reality Emma rejects, the beggar parallels the Duc de Laverdiére. The beggar is, as Sheila Bell has suggested, a "reincarnation of the aristocrat" (28) in an extremely negative manner. The Duke's deafness and "red-rimmed eyes" (Donaldson-Evans 16), signs of aging, will transform to describe the blind man's condition. Emma completely ignores the Duke's senility, focusing only on his past, great wealth, and status. In reality, he is an old graceless man. His "bloodshot" (Flaubert 67) eyes are a form of the blind man's oozing, atrophied

eyes. His inability to articulate his thoughts and his mumbling parallel the beggar's frequently incoherent words. Moreover, other characteristics solidify the transformation from Duke to beggar: "pendulous lips to skin hanging in shreds, dripping sauce to oozing sores, red-rimmed eyes to bloody orbits" (Donaldson-Evans 16). Thus, aristocrats are not the "paragons of health and virility" that Emma imagines they are. Honestly, they are mere humans who age and become decrepit. Both the Duke and beggar demonstrate how time and illness take their toll on an individual. The Duke's true appearance is a far cry from the "tumultuous lives, masked balls, and insolent pleasures" (Flaubert 83) that Emma fantasizes. Hence, he is more similar to the blind man than he is to the other womanizer in the novel, Rodolphe.

In addition to showing the real Duke behind Emma's façade, the blind man reveals the truth behind Emma's fantasy about Edgar Lagardy. He functions to show the transition from pure dreams to reality, something Emma strives to deny. Lagardy, "occupying a position parallel to that of the Duc de Laverdiére as unseeing object of Emma's contemplation" (Donaldson-Evans 16), catalyzes her imaginings about affection and ardor. Similar to the Duke, Lagardy captivates Emma because of his reputation as a womanizer. However, as a traveling performer who sings in operas to earn a living, he foreshadows the beggar. Therefore, Lagardy reinforces the beggar's representation of all that Emma represses. Juxtaposing the "healthy complexion and mellifluous voice" of Lagardy with the beggar's skin lesions and hoarse voice ironically discloses likenesses. Similar to the Duke and beggar pairing, the beggar is the sullied counterpart to Lagardy. The "langorous rolling of Lagardy's eyes corresponds the beggar's flickering pupils; to the former's tale of the tragic romance corresponds the latter's bawdy song." The parallelism between Lagardy and the blind man underline the depth of Emma's illusions as rejecting truth. Thus, the beggar represents how she denies reality.

Not only is the beggar equivalent to Lagardy in the context of aging, he also parallels Emma in circumstances. According to Alison Fairlie, the "loathsome disease which eats away his face is like the decay into which her life is falling" (36). Just as he is helpless to improve his condition, she cannot change her situation. Both are characters in the midst of a terrible decline. He demonstrates that she can "never face a hideous truth as she shudders away from him or melodramatically flings him her last coin." Richard Zakarian believes that the gesture alludes to her financial and moral bankruptcy (25). In addition, the colors blue and green further demonstrate how the beggar and Emma are inseparable. Blue, in Stirling Haig's words, evokes Emma's "mystical and sensual longings" (90). It is the shade that covers all her insecurities, bitterness, and resentment about life in a provincial town married to a boorish mate. It is also an important part of the dreamlike worlds she cannot function without, mostly apparent whenever she fantasizes or romanticizes an object or event. For example, when she reads the love story Paul et Virginie, she remembers and romanticizes her convent education in blue. The "bluish haze" (Haig 83) is the incense that characterizes the Catholic Mass and "convent existence" to which Emma longs to return. During her affairs with Léon and Rodolphe, blue colors her idealization of both men and her joy at having a lover. She wears a blue veil when Rodolphe seduces her. She views Léon in the blue of a sunny sky (Haig 84-85). However, the beggar's green eyes, and the "funeral dirge" (Haig 92) that accompanies them, symbolize repressed reality. They reveal death's agony and the terrible end everyone faces. Emma's demise signals the death of her illusions. While blue haze hangs over her as she dies, her coffin cover is a "large swath of green velvet." Thus, the beggar's greenish eyes are a counterpart to Emma's identification with the color blue, demonstrating how death cannot separate from Emma's imagined life" (Haig 90). Despite firmly holding onto her mirages in the battle against truth, death and reality ultimately defeat her. The fabric serves as their victory banner.

Moreover, along with this parallelism with Emma, the beggar shows the opposite responses

Emma and Homais have to reality. They "represent contrasting ways of coping with the crippling ugliness of life as symbolized by the blind beggar" (Sachs 77). Emma attempts to shield herself from reality, trying to remove it from her conscience. She refuses to see what is actually there. For her, reality is the monotonous provincial life as a dull medical officer's wife and a place where she has no control over her circumstances. Hence, she prefers to inhabit her own romantic world, the world of novels and passionate love affairs, where she can hide from her "distaste for everything and everyone" (Flaubert 82). Reality is a pest to her sensibilities. Consequently, she attempts to avoid the beggar as much as possible. He is an eyesore that she refuses to see, but cannot escape. She would rather have him take all her money than confront the reality he represents. In contrast, Homais exploits reality to his advantage. While he is incompetent and mediocre, he reaps tremendous rewards through seizing opportunities. He looks for how to manipulate the beggar's "existence somehow for personal gain" (Sachs 77). He recognizes reality's ugliness and human weakness, instead of hiding from it. He takes advantage of both for self-promotion. After Emma's death, Homais turns the beggar into his victim, reducing him into an outcast unfit for the slightest human contact. He tears an already depressing figure into shreds, ruining his paltry reputation. Thus, he consolidates his power to make himself grander. The beggar transforms into Homais' last opponent and obstacle on his path to success, becoming the "happiest of fathers, the most fortunate of men" (Flaubert 320). Getting rid of the beggar leaves a clear, unobstructed road toward glory. Thus, Homais triumphs, while Emma degrades into bankruptcy and death.

Not only does the beggar juxtapose Homais' and Emma's opposite reactions toward reality, he also represents, what Sven Bikerts calls, excess "served back in its grotesquely inverted form" (Bikerts 143). The excess Emma falls into leads to obsession and isolation. Lust becomes her obsession, leading her increasingly to alienate herself from the wider world, until her only company becomes the blind beggar. Money, secrecy, and hunger for sexual satisfaction become her sole purpose in life. She also entraps herself in the world she has created. The beggar is the "mocking commentary" on Emma's fate. He reveals life's harsh lessons to Emma and signals the end of her chimeras. His grotesqueness is the perfect accompaniment to Emma's obsessive desire for the loveliest and most expensive. When he receives Emma's last five-franc coin, he becomes the "degraded replacement of Léon and Rodolphe, who had been the beneficiaries of her sexual and economic largesse" (Donaldson-Evans 15). The blind man demonstrates that life is hard. Reality is ugly, not an idealized figment of the imagination. She cannot deny forever that her excessiveness does not have consequences. She must realize that life is difficult and that everyone suffers. One cannot exist in a bubble of one's own creation. The beggar reinforces the brutality of life and death. Misery exists and is an integral part of life. The beggar's poverty and illness coincide with Emma's greed and selfishness. They show the consequences of an excessively lustful life. They foreshadow her impoverishment and her death from arsenic poisoning.

Along with presenting a foil for Emma's excess, the blind beggar's extremely hideous physical appearance emphasizes his representation of reality. He rolls his "glaucoma-affected eyes" (Flaubert 280) and his flesh peels away in strips down his face. He causes shudders and disgust. Due to his shocking exterior, he jolts both the reader and Emma out of fantasy and into reality. He would not become an unforgettable character if he does not make the reader and Emma uncomfortable. His physique and disease emphasize life's cruelty. Nothing happens according to expectations or plan. To live means to confront shock and fears, some of which are extremely grotesque. He is an extreme example of two terrible aspects of reality: poverty and venereal disease. He foreshadows Emma's impoverishment and the dire consequences of her love affairs. To finance her trysts, she exchanges dignity for debt, a selfish scheme. Instead of becoming a happier woman, expenses and lust have made

her isolated and bitter. While she does not suffer from a loathsome illness from her affairs, she does suffer utter agony as she dies from arsenic poisoning. Dying transforms from a romantic path to freedom to a tortuous journey to an empty end. When Emma concentrates on the "peeling plaster on the wall, on two sticks smoking in the fire end to end, and on a large spider climbing above her head in a crack of the rafter" (Flaubert 286) after she comprehends the extent of the damage she has caused, she becomes confronted with terrible reality. The plaster parallels the beggar's skin that peels away from his face. It conveys hideous imperfections, representing how human weakness in the real world destroys idealistic dreams. Additionally, the wall is Emma. Similar to how the wall cannot keep the plaster form peeling, she is powerless to stop her illusions from falling apart and unable to master her life. The firewood signals the lustful individuals, ignoring the consequences of their actions. It refers to the passionate affairs Emma commences with Rodolphe and Léon. Like firewood, her lust intends to burn forever, without regard to consequences. The beggar is the cold water that quenches her burning passion. Exactly like how water destroys the fire, he destroys Emma in removing her intense desires. The spider symbolizes imminent death, which creeps into the crack that remains of her life. It bites into her existence, emitting a toxin that kills all the illusions essential to her survival. It also paralyzes her into seeing human frailty and agony. All three mundane objects are staples of the quotidian, articles which Emma continually avoids noticing, but now cannot. Daily aspects signal the end of not only her dreams, but the life that she constructs with those dreams. Thus, she loses her entire life. The fragile house of dreams she has constructed crumbles into a terrible "memory of her adulteries and miseries" (Flaubert 296). Its "walls were trembling, the ceiling seemed to be crushing her" (Flaubert 291) as reality seeps into her existence.

The beggar's appearance also acts as a tool for pointing out the incompetent in society. In Yonville, that mediocre figure without merit is Homais. His advice to the blind man, stressing consumption of "good wine, good beer, good roasts" (Flaubert 280) as a remedy for his scrofula highlights the discrepancy between the unattainable richness if that diet and the poor man's utter destitution. Homais' only concern is to exploit the blind man for personal gain, viewing him as a commodity rather than a human. His assertion that he can "cure the blind fellow with an antiphologistic slave of his own making" further indicates his incompetence. Despite only a sketchy knowledge of medicine, he knows that his sway within the community makes him stronger than the beggar. He can command the beggar to do anything. Therefore, the beggar's disfigurement victimizes him, making him the prey to Homais' predatory self-aggrandizement. He becomes distinguished as the inferior pawn to Homais' influence. After Emma's demise, Homais unleashes the "depth of his cunning and viciousness of his vanity" (Flaubert 317) to turn the beggar into an ironically, painfully tragic figure. Thus, the beggar cannot be the supernatural incarnation of evil that Demorest and Thibaudet attest.

The predator-prey relationship between Homais and the blind man that develops from the beggar's horrible physique corresponds to the sexual relations between Emma and Rodolphe. Emma refuses to see herself as just another beautiful conquest of Rodolphe's insatiable lust. Her priority is "entering into something marvelous where all would be passion, ecstasy, delirium" (Flaubert 163). However, to Rodolphe, she only exudes "an odor of damp dust and withered roses" (Flaubert 196). Emma is a conquest, a trophy to attain and a doll to play with temporarily. She is more similar to the locks of women's hair "stuck to the hinges of the box" that Rodolphe possesses. Their affair is ephemeral; he has the ability to cast her off when she desires. Like the beggar believing Homais could cure him, Emma ardently assumes that Rodolphe has her best interests in mind, eventually realizing her deception. Similar to how Homais asserts himself as the "victor, for his enemy was permanently committed to an asylum" (Flaubert 318), Rodolphe asserts his victory in denying Emma

financial support, leaving her to decay. Both the beggar and Emma become losers in the game of life.

As the prey in their respective relationships, the beggar's tragic end is analogous to the depressing results of Emma's death. While he becomes locked in an asylum, Berthe, Emma's daughter, becomes the pathetic figure, sent to a "cotton mill to earn her living" (Flaubert 322). Like the beggar, she is a prisoner in a constant cycle of hard labor and exploitation, without hope of escape. Her circumstances reveal the poverty that has continually haunted Emma, but which she has fervently attempted to deny. Thus, the beggar symbolizes the utter ruin and disaster Emma foresees, but which she has employed all means to erase from her conscience. She considers it a "beautiful gesture to squander" (Flaubert 280) her last five-franc piece on the beggar, completely indifferent that she has renounced her entire fortune. She ignores the dire consequences that will befall her husband and child, thereby forcing them to suffer deprivation until death.

In addition to the blind man's horrible visage and his status as prey, he possesses a raucous voice, upsetting to the ear. He also emits "a kind of low howl, like a starving dog" to further emphasize his grotesqueness. His voice only heightens the already negative effect of his face. He is an annoying pest that everyone, especially Emma, wishes to avoid and ignore, but cannot. One sound that the beggar constantly emits is songs. Instead of soothing the environment with their melody, his songs shock with the force of their cacophony. They produce tension, in place of serenity. When Emma has sexual relations with Rodolphe in the forest, she hears a "vague, prolonged cry" (Flaubert 162), a song that foreshadows the beggar's appearance. It is her subconscious that detects reality amid the illusions pervading her consciousness. The song softly approaches her in order to slowly wreak havoc on her illusions. The contrast between the "luminous shimmering patches of leaves" and the voice that "mingled like music with the waning vibrations of her throbbing nerves" demonstrates how a brutal world, that turns individuals into insignificant beings, will enter and overtake a lovely, peaceful, romantic setting. The voice signals how repressed reality will eventually, unexpectedly appear in Emma's life, something which she cannot control. The most memorable song that the beggar sings is the last sound Emma hears before she dies. What is striking about that song is its subject matter: a young woman who dreams of love on a warm summer day (Flaubert 302). Hence, the song's intention is to parallel the woman in the song to Emma, contending that they are the same individual. Emma's reaction, lifting "herself up like a galvanized corpse, her hair undone, her eyes fixed and staring," reveals her complete shock. Her status as the wife of the town doctor reduces to the subject of a blind beggar's song. She dies because she no longer holds any influence. Death is the sole certainty in her life. Only the "hideous face of the beggar standing out against the eternal darkness like a nightmare," truth revealed, is her final outcome. The status she always imagines that she holds has disappeared. Instead of the heroine of a romantic, idealized world, she is the ordinary woman embarking on an ordinary end, death.

While a purely demographic sampling would not come up with a beggar for representing reality, beggars do exist in the real world. They are individuals society often ignores or refuses to see. They must relegate themselves to the shadows as outcasts unworthy to behold. For Gustave Flaubert to use what Sachs calls such a "solitary, mutilated" (Flaubert 302) character to represent reality has several functions. It is a biting commentary on bourgeois sensibilities, very prevalent in the novel. It harshly criticizes the limited outlook of the provincial people, who prefer to live in an illusion of their own making. Like Emma, most of society rejects anything that is unpleasant. In addition, Flaubert intends to shock both the reader and Emma to reality's harshness. When a largely ignored figure suddenly and unexpectedly forms an impression, individuals become transported out of their illusions. Repressed individuals return to haunt those who have shuffled them away. Repression transforms into oppression.

Emphasizing how beggars are not a significant demographic entity, Flaubert utilizes the blind man as a practical joke on his readers to emphasize Emma's denial of reality. A minor, supposedly insignificant, character carries the heaviest weight. He functions to reveal truth in all its terror to a provincial wife gazing "at the solitude of her life with despairing eyes, seeking some white sail in the far-off haze of the horizon" (Flaubert 79). The blind man's duty to shine the light of reality on a hopelessly romantic heroine is ironic. He himself becomes a victim of false hope and deception. Who some interpret as the manifestation of everything evil is truly nothing more than a "poor devil" (Flaubert 280). Removing the cloak of power reveals that he is a helpless outcast, a metaphor for reality's melancholy and doom. The cloak represents the veil that covers reality and produces an illusion. Underneath the cloak is the brutal world that can transform anyone into "almost an idiot."

The blind beggar, the "most grotesque and frightening character" (Haig 91) in Madame Bovary, has incited various interpretations and commentary from many literary critics. Some promote his supernatural qualities, the embodiment of Emma Bovary's corruption and her damnation for her sins. Others see him as a symbol of reality and mortality. However, he is most correctly seen as an expression of Emma's reality and reality's harshness.

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TUPE or Not TUPE?:
The Impact of Labor Regulations on Business Transfers: A Comparative Case Study Approach to Labor Laws in the UK v. US.

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Abstract

The British TUPE regulations, amended in 2006, restrict the employment flexibility of businesses operating in Britain. The purpose of the TUPE legislation is to provide a greater balance of power between businesses and their respective employees by requiring employee work contracts to transfer unmodified to new ownership during a business transfer. Conflicting with capitalism, these laws create friction between American corporations and British domestic business. Furthermore, the liabilities associated with the application of the TUPE laws are difficult to quantify due to conflicting court decisions. As a

result, American companies, who are unaccustomed to the socialist value system, are becoming less likely to operate in Britain. Through a capitalist lens, the following report identifies the positive and negative effects of the British TUPE regulations and analyzes the responses of American business to the additional liabilities created under TUPE. Prior literature has failed to relate American capitalist values to the socialist TUPE laws. This paper also serves to provide Americans with an understanding of the significance of the TUPE regulations and their potential impact on future business interactions in Britain. While it only studies a small segment of business law, this report is important because it depicts a modern-day example of the business complexities associated with a free versus a regulated market. la vie d'Emma et de sa fin [a symbol of Emma's life and her end]" (Demorest 468). Similarly, Albert Thibaudet contends that the blind beggar is "une figure de damnation [a figure of damnation]" (96), hovering over Emma's demise. He is the grimacing monster that menaces her during her travels to Rouen and reminds her of her adultery. When she gives him her last piece of silver, she is essentially giving her sinful and corrupt soul to him. She dies with an atrocious laugh, connected to the beggar's song that she hears. Likewise, Harry Levin argues that the blind beggar is a monster, a "memento mori" (265). For Levin, he symbolizes human frailty.

TUPE or Not TUPE?

WHAT DEGREE OF POWER SHOULD EMPLOYERS HOLD?

The difference between the American system and British TUPE laws are a classic example of the struggle for a balance of power between corporations, governments and employees. The TUPE regulations create complicated entry barriers for American business owners that attempt to acquire, outsource or merge with a business in Britain. In addition to the transfer of ownership, the TUPE laws require the transfer of unmodified employment contracts and employee benefits. For business owners, this means that they face substantial financial liabilities if they attempt to flex the workforce to eradicate labor inefficiencies within the new corporation. Furthermore, because of inconsistent court rulings, British lawyers cannot accurately predict the liabilities and subsequent costs incurred when an employee sues under the TUPE laws for contractual modifications or wrongful termination of employment. Refer to Appendix A for specific examples of recommendations from British lawyers.

Prior literature has failed to offer an American perspective on the complications that surround the inconsistent applications of procedural law regarding labor regulations upheld by the TUPE laws. This paper attempts to provide American companies with an understanding of the significance of the TUPE regulations and their potential impact on future business interactions in Britain.

DEFINITIONS

For purposes of this paper, a *business transfer* is any relocation of business to different management. This includes: 1) the outsourcing (paying Company A to do a job for Company B that Company B previously conducted itself), 2) in-sourcing (Company B deciding to perform a job itself that it previously paid Company A to do), or 3) complete transfer of business activities (Company A purchasing Company B or a branch of Company B).

US EMPLOYMENT OBLIGATIONS DURING A BUSINESS TRANSFER

US common law does little to protect employee rights during a business transfer to another national company. American companies are not obligated to continue employment contracts during transfers and have the ability to modify the terms of individual employment contracts as they see fit. For example, when Texas-based company Genlyte Controls acquired another US lighting company, Vari-Lite, Genlyte laid-off 58% of Vari-Lite employees and changed several employment contracts to lower the workers' salary and vacation. These alterations were necessary to reduce the overall

financial losses being incurred due to the inefficient allocation of the company's resources. Though an extreme case, the Genlyte acquisition of Vari-Lite demonstrates the freedom American businesses have to flex their workforce and employment contracts at will.

However, outsourcing to specialize in a task in the US is not necessarily synonymous with job loss. When General Motors decided to outsource all of its employees that work in the cafeteria to the Marriott, the cafeteria workers that were laid off were then rehired by Marriott. While outsourcing a job, both companies have the ability to change employment contracts and flex their workforce at will. The US grants companies full control over employment contracts which may be altered or cancelled at any time for any reason.

BRITISH BUSINESS REGULATIONS DURING TRANSFER: THE PURPOSE OF THE TUPE LAWS

The Transfer of Undertakings: Protection of Employment (TUPE) act requires the new employer to accept the transfer of all employees, conditions under which they operate and the liabilities associated with them from the original employer. In other words, employees are guaranteed to continue working in their original job with the same salary and benefits in the event of a business transfer. TUPE was established in the UK to encourage business organizations to find a balance between the free market in which they operate and the perceived social obligations to their employees.

HISTORY OF BRITISH EMPLOYMENT LAWS: INTEGRATION THROUGHOUT THE EU

The European Union (EU) adopted the Acquired Rights Directive (ARD) in 1977 in an attempt to link business market flexibility with international employment security.[a] The social directive outlined regulations to safeguard employment contracts during a business transfer because the EU was attempting to distribute market growth throughout society.[b] Though many EU countries were hesitant to adopt the directive, the UK's stringent adaptation of the ARD in the form of the Transfer of Undertakings: Protection of Employment (TUPE) legislation greatly influenced the prominence of the directive throughout the EU.[c]

Written in 1981, the original TUPE legislation caused a spasm of confusion for businesses in the UK, as inconsistent court decisions set conflicting precedents. In the 1985 court case, *Angus Jowett & Co. Ltd v. National Union of Tailors and Garment Workers*[d], the court decided that the liability to consult and inform employees of a transfer belonged to the former rather than current employer. However, in the 2000 case of *Kerry Foods Limited v Creber and Others*[e], British courts decided that the failure to consult was in breech of the employment contract and therefore the obligation to consult and inform employees of a business transfer became the responsibility of the new employer.[f] *Kerry Foods* and *Angus Jowett* are two of the many examples of how inconsistent interpretation of the TUPE laws led to "substantial and unforeseen compensation and business costs, significant legal costs and the diversion of a significant portion of management time" for businesses operating in Britain.[g]

CURRENT SCOPE OF TUPE

The inconsistency in court rulings necessitated clear legislation amendments that came in the form of TUPE 2006. British businesses currently operate under these amendments.

a http://www.emplaw.co.uk/researchfree-redirector aspx?StartPage=data%2f11001802.htm

b http://www.eurofound.europa.eu/areas/industrialrelations/dictionary/definitions/acquiredrightsdirective.htm

c "'Entrepreneurial Freedom v Employee Rights': The Acquired Rights Directive and EU Social Policy post-Amsterdam," Steven Hardy

d **Angus Jowett & Co. Ltd v National Union of Tailors and Garmet Workers**, 1985 I.R.L.R 326

e **Kerry Foods Ltd v. Creber and Others** [2000] ICR 556

f "Social and Labour Rights In a Global Context: *International and Comparative Perspectives,"* Bob Hepple

g Business Services Association, 1996

After the 2006 TUPE amendments, the current scope of TUPE:

- Includes transfer of the initial contract, change of contractor or vertically integrating servicesh
- Incorporates both professional and service industries
- Permits contractual variation only if it is solely due to an economic, technical or organizational challenge and additionally includes flex of the workforcei
- Incorporates provisions for greater flexibility in insolvency transfers[j]

Requires information about employees to be given to the new employer prior to the transfer and requires the new employer to notify employees of the transfer within "sufficient time"[k]

APPLICATION OF TUPE

The TUPE legislation is enforceable anytime a part of a business changes hands, including outsourcing, change of contractor or in-sourcing.[l] The TUPE laws are applicable during a change of contractor, enabling the employees previously contracted solely to work on one company's case to switch their employment to the new contractor.[m] In other words, if Company A switches from Contractor B to Contractor C, Contractor C is legally required to offer the same employment contracts to all displaced employees formerly working for Contractor B solely with Company A. Finally, when services are brought in-house, the employer is legally obligated to hire all of the employees under their original contract.

h "2006: The Year of Employment Law", Press Briefings 2006
i "Contractual Variations During a TUPE Transfer: Can or Can't You?" Christina Tolvas-Vincent, 2007
j "Banking & Insolvency Update: TUPE 2006 to the rescue…?", Olswang, 2006
k "Transfer of Undertaking (Protection of Employment) Regulations 2006", Robin Broughton, 2006
l "Employment Aspects of Outsourcing", Freshfields Bruckhause Deringer, 2006
m http://www.business-strategies.co.uk/Products%20and%20services/Micromarketing%20data/Business%20segmentation.aspx

TUPE INCLUDED IN THE PROFESSIONAL DIVISION

Created originally for the purpose of blue collar workers, the 2006 TUPE amendments expanded the scope of TUPE to the professional sector. Following these amendments, displaced employees at advertising agency McCann Erickson used TUPE in an attempt to transfer their contract employment from McCann to Euro RSCG after their contract with Boots Healthcare was cancelled and switched to Euro RSCG.[n] Although the court decision remains unconfirmed, legal opinion is that the McCann Erickson employees have the right to transfer to the new advertising agency.[o]

CONTRACTUAL VARIATIONS

The amendments passed in TUPE 2006 only allow change in employment contracts if there is an economic, technical or organizational reason such as harmonizing employment benefits. It is important to note that employers are only allowed to flex their workforce or change employment contracts during a transfer in the case of contractual variations. In such cases, employers must both flex the workforce and enforce some contractual variations in compensation or vacation time.

Previous court cases have established that it is extremely hard to prove that decisions were based on economic, technical or organizational reasons and have most frequently ruled in favor of the employees during a TUPE lawsuit. Most companies, therefore, do not change their employment contracts in fear of lawsuits.

INSOLVENCY TRANSFERS

The TUPE amendments allow changes in employment contracts if the business is bankrupt and if the employees agree with the set contractual variations.[p] Because

n "Much Lies in Store for TUPE laws in 2007", Dr. John McMullen, 2007
o http://www.hrmguide.co.uk/hrm/steele/october06.htm
p "'Entrepreneurial Freedom v Employee Rights': The Acquired Rights Directive and EU Social Policy post-Amsterdam," Steven Hardy http://www.tupeconference2006.com/downloads/pdf/TUPE%20The%20New%20Regulations%20June%202006%20conference.pdf

a business bankrupts when their costs are higher than the sales, one must either cut costs or increase sales in order to save the business.[q] The amendments allow changes in employment contracts so long as the changes are designed to save the failing business, are agreed upon by the employee union, and the workforce is flexed.[r]

TRANSFER OF REQUIRED INFORMATION

Both the original employer and the new employer are required to inform their employees of a business transfer in "adequate time".[s] If the original employer disregards their duty to supply an adequate amount of information about the employees or if the new employer neglects their duty to inform their employees of the transfer, the negligent party is responsible for any damages to the employees of at least £500 per affected employee.[tu]

BUSINESS IMPLICATIONS OF TUPE LAWS

The lack of laws protecting terms of employment during a business transfer allow American companies to adjust their workforce based on the "invisible hand" that guides the marketplace.[v] The UK TUPE laws, however, force British businesses to find a balance between acting in the best interests of the company and acting for the good of individual employees.

APPLICATION OF TUPE

The 2006 amendments that clarified the scope of TUPE to include all transfers such as outsourcing, in-sourcing and contract change, constrain UK businesses from making labor cost cuts during a business transfer.[w] To compete with price on a global level, UK businesses must therefore cut costs elsewhere in the production. The application of TUPE to outsourcing directly works against segmentation, the business practice of outsourcing industry sectors to focus on one particular task. Focusing on specialization more efficiently allocates resources, including labor. Labor cost savings can be allocated throughout the supply chain to reduce the overall cost of production, thus increasing the profitability of a business. However, the provisions of the TUPE laws that restrict the renegotiation of employment contracts or flexing of the workforce make it difficult for companies to add value to their organizations by taking advantage of cutting labor costs.

For example, if a technology company acquires another technology company in order to increase brand image, acquire particular intellectual property or reduce industry competition, they may have duplicate employees in, for instance, the finance department. As a result, the increased costs of production incurred by additional labor costs can erode competitive advantage for the firm.

TUPE IN THE PRIVATE SECTOR

Many problems arise with the expansion of the TUPE laws to the professional sector. Firstly, outsourced professions such as IT and advertising require creative thinking that may not match the objectives of the company that hires them. In the case of McCann and RSCG, where the McCann employees may be transferred via TUPE to RSCG, the employees hired to work solely on Boots Healthcare's advertisements may not have produced advertisements that were consistent with the developed image of Boots Healthcare. Because advertising is a creative and subjective profession, conflicts may arise under new management direction and in some cases, different corporate cultures may be sufficiently incompatible with the client. However, TUPE 2006 can be interpreted to mean that the contractors working for Boots Healthcare during their switch from McCann to RSCG would also transfer to RSCG and would continue their employment for Boots Healthcare, which does not take into account the business needs of the client. As a result, in order to retain control

q www.out-law.com/page-448
r "THE TRANSFER OF UNDERTAKINGS (PROTECTION OF EMPLOYMENT) REGULATIONS 2006: REDUNDANCY AND INSOLVENCY PAYMENTS", Secretary of State, 2006
s "Tenders, Beware of the New Tupe 2006", Kathrine Kay 2006
t "Transfer of Undertakings (Protection of Employment) Regulations", Jane O'Hare, 2006
u http://www.workplacelaw.net/forum/thread.php?thread_id=1409
v Smith, Adam: The Wealth of Nations, page 485
w "2006: The Year of Employment Law", Press Briefings 2006

of their image, companies may be more inclined to internalize particular services that foreign companies are outsourcing more efficiently.

This applies to all professional services: "if you had an organized grouping of solicitors at a law firm devoted to one client, and that client said 'I do not want this law firm, I will appoint law firm X,' then TUPE 2006 could apply so that – contrary to what the client is expecting – it may find that the lawyers would have the right to turn up at the newly appointed law firm."[x] (John McMullen)

Secondly, the transferred contractor, in this case RSCG, may be forced to hire new employees that they may not want to for reasons such as limited office space.[y] Alternatively, businesses may want to have a consistent workforce and might want to retain their employees even after the loss of a contract such as Boots Healthcare. In any of these cases, the TUPE 2006 legislation puts businesses into situations where they may not be able to decide if the individual employees working for their company are well suited for their organization.

CONTRACTUAL VARIATIONS

Harmonizing employment contracts can be important to stabilize employee conflict and to simplify accounting procedures. Although the TUPE laws address the issue of harmonization, employers must demonstrate proof that the contracts were changed solely due to an economic, technical or organizational reason. Courts generally rule in the favor of employees. Because of their fear of lawsuit, new employers find it hard to integrate transferred employees into their business.[z] Newly transferred workers have the potential to operate under a different contract of employment than more senior employees, causing a misalignment in seniority, vacation time, salary and benefits. This has the potential to create division in businesses where more senior employees may have had less employment befits than the newly transferred employees.[aa]

The legislation is further complicated because it additionally requires the organization to flex the workforce. In the case of *London Metropolitan University v Sackur*,[ab] where London Metropolitan attempted to harmonize terms and conditions of employment without flexing the workforce, the university was sued because they failed to demonstrate reasons for contractual change by decreasing the workforce.[ac] This requirement to flex the workforce obligates businesses who want to harmonize employment contracts to decrease the workforce. The legislation which is written to protect employment actually requires businesses to choose between corporate strategy and individual employment. In the case of *London Metropolitan,* the result was unnecessary unemployment.

INSOLVENCY TRANSFERS

The new regulations loosened existing requirements for the transferring of bankrupt businesses so as to encourage organizations to invest in struggling businesses and thereby sustain employment. Because of these amendments, employment contracts can be altered as means of preserving business operations.[ad] Encouraging investments in failing businesses should boost the economy by sharing business technology and information as well as prevent unnecessary lay-offs.

However, because of conflicting court precedents, British lawyers cannot give sound advice as to whether or not the court will side with the business or the employees when claiming insolvency transfer as a reason for flexing the workforce. Without confirmed advice from lawyers, businesses often choose not to salvage the business rather than keep the insolvent business running and face potential TUPE liabilities.

Such is the case in Genlyte Controls and

x "Analysis: British Law May hurt Indian Outsourcers" John McMullen, 2006

y http://ezinearticles.com/?3-Ways-Of-Escaping-TUPE-2006-Service-Provision-Change-Transfers&id=383578

z "'Entrepreneurial Freedom v Employee Rights': The Acquired Rights Directive and EU Social Policy post-Amsterdam," Steven Hardy http://www.tupeconference2006.com/downloads/pdf/TUPE%20The%20New%20Regulations%20June%202006%20conference.pdf

aa http://www.workplacelaw.net/forum/thread.php?thread_id=1409

ab London Metropolitan University v Sackur and Others EAT/0286/06

ac http://www.incomesdata.co.uk/indexes/briefcases2006.htm

ad "Much Lies in Store for TUPE laws in 2007", Dr. John McMullen, 2007

Strand, where an insolvent business transfer led to more unemployment than necessary. When Genlyte Controls acquired Strand, a bankrupt company, Genlyte wanted to keep the UK-based manufacturing plant open for three months while the headquarters moved to the US. This three month period would have allowed the employees more time to find new jobs and would have provided a smoother business transfer as there would not be a halt in manufacturing. However, because the goal of Genlyte was not to save Strand-UK but to move it to the US, the employment liabilities fully transferred to Genlyte and the employment contracts could not be altered. With liabilities of over £50 million[ae], Genlyte decided to halt manufacturing operations and employees were not able to work the extra three months.[af] In this particular case, it would be best for both the employees and the business if the employees were able to waive their TUPE rights.

BENEFITS OF TUPE

According to David Coats, regulated labor markets perform better in the areas of productivity growth and wage equality than flexible labor markets.[ag] The TUPE Labor regulations do increase productivity growth because they eliminate the need to train new employees, increase employee job security which boosts employee moral, provide relevant economies of cost and remove the need to negotiate contracts.[ah]

Finally, regulated labor markets definitely perform much better in the area of wage equality. This, in fact, is the goal of TUPE: to transfer wealth throughout the employment chain.

AMERICAN BUSINESS' RESPONSE TO TUPE

American companies operating in Britain have had difficulty understanding British employment laws under which they must function and the liabilities that are synonymous with the TUPE employment laws. This difficulty has translated, in several instances, to a hands-off approach to business transfers. Most American companies, when faced with the potential liabilities that could be incurred by flexing their workforce during a business transfer, have declined direct business transfers or have waited for the company to declare bankruptcy, thereby losing all employees, before initiating an acquisition. This hands-off approach to business transfers is due to the ambiguous risk of the potential liabilities and the inability to manage the workforce.

TUPE laws discourage international investment in Britain because they place high liabilities on newly transferred businesses without much guidance as to whether or not the court will enforce the liabilities. The lack of decisive court cases have prevented lawyers from being able to give sound advice as to whether or not the courts will rule in favor of the company, or in favor of its employees. This ambiguous risk deters international companies from entering into the British market through business transfers.

Furthermore, most American companies are not willing to acquire, start or expand a business in the UK because they are given very little control over who works for them and at what price. Even contractual agreements are subject to TUPE transfers, regardless of the potential risk to clients. Every British company is restricted by the TUPE regulations, unless they are completely vertically integrated or internationally outsourced.

TUPE / ARD FUTURE PREDICTIONS

Individual adaptations of the ARD across the European Union question the overall scope of the ARD legislation. German courts recently concluded that the ARD applies to international transfers in the case of *Englischer Dienst* where an editor of an internet news service lost his job when his company was transferred from Hamburg, Germany to Cork, Ireland. He subsequently sued and won because the German court decided that a transfer of undertaking could

ae Interview: Edward Wanambwa; 17/03/07
af Interview: Steven R. Carson; 02/04/07
ag David Coats, "Whose Afraid of Labour Market Flexibility?"
ah http://www.out-law.com/page-448

take place across international boarders.[ai] This case decision legitimizes the question as to whether the British TUPE legislation can be applied internationally.

CONCLUSION

American businesses have less governmental regulations and therefore rely heavier on Adam Smith's "invisible hand" of market balance. In comparison, British businesses are heavily restricted by the TUPE laws, which conflict with pure capitalism because of their many employment regulations.

The TUPE legislation provides a greater balance of power between business and its individual employees. For employees, there are many advantages to the TUPE regulations: they encourage consistent work for employees during business transfer and ensure equivalent working conditions to keep a high standard of living. The business advantages of the TUPE laws tend to be less quantifiable, as much of the benefit is in the increased morale of employees.

Regardless of the benefits, the TUPE laws seem economically infeasible because they disallow companies to flex their workforce and thereby cut costs. It appears that the TUPE laws are creating a false sense of security – they encourage a consistent workforce even when a company is segmenting to focus on one task. Segmenting should decrease inefficiencies in areas such as labor which should allow a company to decrease their labor force. Because the TUPE laws make it difficult to cut labor costs, outsourced companies must either cut costs elsewhere or charge more for their services. In a supply chain, charging more for services will advance from the original cost inefficiency to the end-product. This will increase the cost of the end-product which may result in the inability of the product to compete with products from markets where the labor is not regulated.

The conflict between the TUPE legislation and American common-law is the epitome of the persistent debate over the appropriate allocation of corporate and government power. It is clear that the TUPE legislation has positive social intentions, but its over-zealous application has damaging business implications. Legal liabilities resulting from the TUPE legislation are shown to discourage American involvement in the British domestic economy. In essence, the direct conflict of socialist and capitalist values restricts the flexibility of companies to move between two similar economies and jointly benefit from international commercial relations.

ai http://www.personneltoday.com/Articles/2007/01/09/38777/much-lies-in-store-for-tupe-laws-in-2007.html

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APPENDIX A

Dear all,

I write with an answer to a question that arose during today's conference call. Namely, whether asking Strand Lighting UK Limited ("Strand UK") or the insolvency practitioner to dismiss all 60 employees of Strand UK and then reemploying a limited number of them after the acquisition would serve to limit the liabilities that would transfer under TUPE.

The starting point is that all employees who are genuinely redundant (in this case because there is a reduction in the need for employees of the types dismissed or employees of the types dismissed in the location in Kirkcaldy or Cambridge) could be fairly dismissed and if so they would only be entitled to their statutory and contractual redundancy payments (as well as pay for the notice period). However, it can be harder to show a genuine redundancy when a transferor makes employees redundant at the insistence of a transferee and as such there could be potential unfair dismissal liabilities even in connection with employees who appear to be genuinely redundant

Whether TUPE applied would turn on whether the decision to dismiss was connected to the acquisition by Genlyte. There is a very high probability that the redundancies would (as they are in reality) be found to be connected to the acquisition by an employment tribunal. If the dismissals were not connected to the transfer, no liabilities would transfer to Genlyte.

However, if the dismissals were connected to the acquisition by Genlyte (which is a very likely scenario) then as per my e-mail earlier today, the statutory redundancy payment liabilities would remain with Strand UK but the contractual redundancy payment liabilities would still transfer to Genlyte.

Assuming the redundancies were found to be connected to the acquisition, your proposal to immediately reemploy certain individuals comes with an added risk. The reason being that the reemployed employees would not have been genuinely redundant

at the time of dismissal and this would be evidenced by the fact that they were reemployed in their old jobs. An employment tribunal would be very likely to see though this arrangement to get around TUPE. Any of the reemployed employees who had one year's service would have a claim for unfair dismissal (in connection with which maximum liabilities would be £67,100 per employee) although employees without one year's service would not be eligible to claim unfair dismissal. In both cases the employees would be entitled to contractual and statutory redundancy payments even though they were immediately reemployed given that redundancy would have been the stated reason for dismissal. The unfair dismissal claims of employees with one year's service would probably be well below the maximum amount given that their main head of damages would be for future loss of earnings and they would have been immediately reemployed, albeit perhaps on slightly less favourable terms and conditions.

Hence, in the case of both the employees who were not reemployed and those who were reemployed the net result is that the statutory redundancy payment liabilities would remain with Strand UK whilst the contractual redundancy payment liabilities would still transfer across to Genlyte and there would be additional liabilities (albeit that no claims may materialise) connected with possible unfair dismissal claims.

Hence, the proposal to dismiss all employees and reemploy a limited number of them in their old jobs would actually increase the liabilities that would transfer under TUPE, assuming as is likely the redundancies were found to be connected to the transfer.

Kind regards
Edward Wanambwa

Forwarded by Steve Carson/CONTROLS/GLYT on 03/06/2007 12:19 PM

Texan and American, the Dual Identity: A History of the Texas Militia and Its Relation to Identity

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Abstract

The Second World War marked a period of intense nationalization in the United States, but this was only the acceleration of a process underway since the early days of the Republic. The gradual federalization of state militias, long representative of American animosity toward centralized government, and in particular, the nationalization of volunteer companies of nineteenth-century Texas serve as a prime example of the trend. Their evolution from colonial defensive regiments into the twentieth century National Guard units, such as Texas' 36th Infantry Division, demonstrates both the expansion of power by

the federal government and the changing perceptions about what it meant to be an American and a Texan.

Texan and American, the Dual Identity: A History of the Texas Militia and Its Relation to Identity

Although the notion of a unique Texan identity presents itself throughout the myriad works on Texas History, none that I came across during my studies focused solely on the juxtaposition of Texan and American identities—how those living in Texas viewed themselves, as Americans, Texans, or both. The fluidity and intangibility inherent in the concept of "identities" made the subject a tricky one, and to better define the chronological and historical parameters, I chose to study the concept of Texan and American identities through the story of the militia system in Texas.

Books and articles on the Texas Militia, Texas National Guard, and Texas military experiences abound; but none adequately defined what I felt was an underlying and essential component to the soldiers of Texas: How did these men of different eras identify themselves? What I found was a complex set of answers, as different as the number of men I read about. At the same time, however, each history, story, article, or diary demonstrated to some extent a dual allegiance, and a parallel narrative of Texan and American identities emerged. With its state and nation (or state versus nation) structure, the federal form of democracy is innately dual, but the historical inheritance of Texans, real and mythologized, gives Texas a particularly strong following of allegiance no longer found in other states or regions.

Therefore, owing to the relative stability of the militia system as a traditional Anglo-Saxon institution throughout American history into the present and also to the strong ties of Texans to their State, I have attempted to analyze the self-identification of Texans as affected by and as affecting various military forces of Texas, namely the Texas militias and Texas National Guard. At the same time, the story of the Texans is recognized as part of a larger American history and the evolution of the militia system as a part of the greater trend of national unification throughout the history of the United States.

Gone To Texas: Americans Turned Texians

When Stephen F. Austin's Anglo-American colonists crossed the Sabine River into the Mexican province of Texas in 1823, they brought with them the tradition of the American militia system.[1] Although similarly inherited from the English, the American perception of militia transplanted into East Texas had undergone a fundamental shift during the period of English colonization and the American Revolution from a tool of the central government to a means of protection *from* the central government. A centralized system with sufficient force might impose unjust laws on the land and usurp individual, local, and states' rights. The citizen soldier insured that trained troops would be available in times of crisis, but could be disbanded at the conclusion of hostilities. Disbanding them meant eliminating a potentially dangerous tool of centralized oppression while simultaneously saving money.[2] According to John K. Mahon, scholar of the National Guard, the concept of the American-style militia springs from the fear of an arbitrary central government in control of a large standing army. In the United States, the distrust of central government and apprehension toward a national army stemmed from colonial conflicts with the British and the resulting American Revolution. The clash with the central government and the sovereignty enjoyed by the colonies and early states focused the identities of contemporary militiamen and general citizens toward the state and local levels.

Many of the early "Texians," as they were originally called, had moved to the Mexican province of Coahuila y Tejas from the American southern states, and still viewed themselves as citizens of the United States, despite Mexican laws requiring all immigrants to adopt Mexican citizenship and be baptized into the Catholic faith. Those immigrants believing Texas to be American soil traced their claim to the Spanish-American dispute over the boundaries of the

1803 Louisiana Purchase. Even though Secretary of State John Quincy Adams recognized Spanish control over the province of Texas in return for the cession of Spanish Florida in the Adams-Onís Treaty of 1819, most Americans considered Texas a rightful part of the United States, a natural addition in the expansion toward the Pacific.

During the Texas Revolution a new Texan identity began to emerge. It incorporated many aspects of the cultural components of Mexican Texas, such as boots, "cowboy" hats, Mexican saddles, and ranching; but it was also related to the overall American character.[3] This is evidenced by letters, speeches, and political views of the day. In his famous letter from the besieged Alamo in late February 1836, Colonel William B. Travis describes his desperate situation "To the People of Texas & all Americans in the world."[4] Similarly, José Antonio Menchaca, a Tejano army officer fighting for independence, expressed acceptance of a general American identity during the Battle of San Jacinto on April 21, 1836. A captured Mexican officer pleaded to Menchaca for quarter as a "brother Mexican," only to be rebuffed by Menchaca, "No, damn you, I'm no Mexican—I'm an American."[5] The identification of Texan with American is unmistakable in the case of Menchaca, as he was born a Mexican in the province of Texas, but felt he had become an "American" by fighting for Texas independence. The self-identification of early Texians as Americans is most apparent amongst the populace in the strong push for annexation following the revolution.

The majority of Texians sought annexation by the United States immediately following the Texas Revolution. In the first national election, held in 1836 and by which Sam Houston was elected President, Texians voted almost unanimously for the annexation of their fledgling republic by the United States; however, a sectional struggle for power in the United States placed the heretofore widely accepted view of U.S. westward expansionism into Texas at the center of debate for an increasingly regionally factionalized America.

One fear of Northerners was that the admission of a large and possibly powerful Texas would upset the tenuous balance between free and slave states, as well as draw the United States into a war with Mexico. Even recognition of Texas as an independent republic was withheld for some time and did not pass in the U.S. Congress to be signed and granted by Andrew Jackson until literally the eve of his leaving the Presidency. With such ambivalence from the United States, a sense of honor was wounded in Texas, and an anti-American party started to gain prominence.[6]

For those Texians hoping to maintain independence from the United States, this identity was based on a new North American republic that was not apprehensive about expansion. Mirabeau B. Lamar, second President of Texas, and his followers envisioned an empire stretching all the way to California, and the Texas legislature passed a resolution claiming the Californias as Texas territory.[7] In 1841 the Santa Fe Expedition was sent as an unsuccessful attempt to enforce Texas sovereignty over the New Mexico region, which was still part of the Mexican Republic. Although these beliefs might be viewed as nothing more than a strong undercurrent during the Republic owing to popular support for American annexation, they still played a critical role in defining a Texas self-image of the land-rich, independent, frontiersman. Similarly, the Anglo belief in manifest destiny demonstrated an accord with American expansionists, and foreshadowed the Mexican-American War.

Even more important to the self-identification of early Anglo-Texians was the bellicose atmosphere that hung over the young Republic and Mexico. The Revolution had been won by an alliance of Anglos, Tejanos, and Mexican Federalists, but the tensions and fears caused by Mexican invasions, including General Adrián Woll's capture of San Antonio in 1842, created suspicion amongst Anglos about the loyalty of Hispanic Texians. Linguistic and cultural differences, especially between native Hispanics and post-Revolutionary Anglo-immigrants, further marginalized Hispanic Texians, and Tejano heroes of the

Revolution, such as Juan Seguin, found themselves literally pushed out of the country they had helped to create.

It was during the years of nationhood, from 1836 to 1846, while a definition of what it meant to be a Texan was forming, that local communities formed irregular ranger and militia companies to supplement the Republic's small army and cavalry forces. Little is known of these early militia companies, but the autonomy from centralized control is evident in the equipment issued (or rather, *not* issued) by the Republic. Each man in groups such as the Milam Guards of Houston and the Galveston Artillery supplied his own equipment. Almost no semblance of uniformity existed.[8] A copy of the 1840 constitution of the Travis Guards demonstrates the local autonomy enjoyed by militias, stating that such groups were not only expected to raise funds through membership dues, but were also permitted to elect their own officers and administrators.[9]

During the Republic, a united image of "Texans" was formed. The definition of Texans had come to be defined racially, as Tejanos who served during the Revolution and in early government posts were marginalized. Among Anglos, some had had aspirations of a grand empire separate from the United States, but even those who had sought annexation all along still had a hand in an independent experience in revolution and nation-building. They had joined the United States of their own accord, had come in with a land area far greater than any other contemporary state, and had maintained the right to manage their own public lands.[10] At the same time, the local and states' rights traditions of the Southerners who settled the lands combined with the local autonomy and independence created under a weak national government during the Republic, meant that the people of Texas would retain a strong component of their separate Texan identity even after finally becoming Americans.

Americans at Last and the Confederacy

When Anson Jones lowered the Texas flag and raised the United States flag over the Capitol in 1846, the Texas militia came under the directive of the United States Constitution and the Militia Act of 1792. Indeed, the Constitution itself points to the fine line that existed between federal and state control of these militarized units. According to Article I, Section 8:

> *[The Congress shall have the power] To provide for organizing, arming, and disciplining, the militia, and for governing such part of them as may be employed in the service of the United States, reserving to the states respectively, the appointment of the officers, and the authority of training the militia according to the discipline prescribed by Congress;*[11]

The 1792 act of Congress attempted to regularize the various state militias.[12] This first step toward nationalization was the consequence of the inconsistent performances of militias throughout the American Revolution, a pattern repeated until the Civil War.[13] For the most part antebellum militias functioned more or less as "social clubs," and the roll calls of ordinary militias, as opposed to the better trained volunteer groups, were used as a census gathering technique for all men ages eighteen to forty-five.[14] Between annexation and the onset of the Civil War, frontier and border defense came under the jurisdiction of the U.S. army, though a large number of Texas militiamen volunteered to ride across the border into Mexico in the Mexican-American War.

Born out of the annexation of Texas and the American desire for Westward expansion, the Mexican-American War was the culmination of the smoldering border warfare that had existed between the two different civilizations of the United States and Mexico. Men who had been united against Mexico during the Texas War for Independence found themselves on different sides, as Tejanos who had been pushed from their homes either volunteered or were forced into Mexican service. On the other side, many mounted Anglo-Texans composing the Texas Rangers gained renown in American victories

under Generals Zachary Taylor and Winfield Scott. Commanded by men such as Jack Coffee "Jack" Hays and Samuel Walker, the Rangers earned a fearsome reputation and became known as "*los diablos Tejanos*" amongst Mexican guerillas.[15]

Such volunteerism on the part of Rangers and militiamen demonstrates another trend toward nationalization: the militias began to be viewed merely as training grounds for troops who volunteered for national service during times of war; and as former militiamen organized into federal companies, the esprit de corps that had materialized from group training under state jurisdiction disappeared. By dissolving the state militias in favor of a nationally unified army, the militiamen were shedding their state identities for a general American identity. Nations are often most united during times of war, and a degree of that centralization usually carries over into the post-war period. This is also true of the militiamen in Texas. When they traded in their identities as soldiers of Texas to become soldiers of the United States, they were reinforcing their identities as Americans.

Although a shift toward nationalization had begun in the late eighteenth century, the foundations for future centralization lay in the Civil War. The Federal victory over States' Rights in 1865 ensured the authority of the national government would reign over all local matters, including the militias. Approximately 91,500 Texans mobilized for the American bloodbath, including those who joined Hood's Texas Brigade, judged by some to be the best unit in the Confederate Army and the ancestor of the Texas 36th Infantry Division of the twentieth century. However, these enlistment numbers only represent those individuals volunteering or drafted for Confederate and Union service.[16] Texas also had to maintain the home front against Indians, Union invasion, and Union saboteurs; thus the Texas legislature created the State Troops from the militia system.

Texas and the Confederacy drew a clear line between those men choosing state or regular army service, and for ordinary soldiers, membership in the State Troops meant protection from conscription by the central government. Federal soldiers arriving in Texas following the war dispersed these local militias; thereafter, the Reconstruction Acts of 1867 eliminated any hope of organizing militias for frontier and border defense.[17]

The Civil War united Southerners under a common regional identity, yet the South was fighting to preserve the sovereignty of individual states. The relative decentralization of the Confederacy combined with the separation of soldiers into fighting units based upon states and municipalities reinforced the state identities of people in the southern states. This was especially the case in Texas, where the state had to take on responsibilities previously allocated to the national government such as border defense.

Americans Again: Forging a United Identity

The ratification of the Fifteenth amendment in 1870 brought Texas back into the Union, and permitted the state to reorganize its militia. Even with Carpetbagger Republicans shaping government, animosity to centralized control persisted enough to cause serious debate in the State Senate on the 1870 militia bill. Many Senators aimed to limit the governor's powers to impose martial law and activate the militia.[18] The possibility for unprecedented nationalization after the war was nonetheless clear, a point well made by Senator W. H. Parsons in a speech during the debate:

> *We here observe that the final adoption of the word 'nation,' and the authoritative recognition of its constitutional significance hereafter as expressing sovereignty in one common government, in lieu of its diffusion among a group of thirty-six sovereignties, is the culminating event—the inexorable logic—the settled result—the accomplished fact—of the recent triumph of Federal arms.*[19]

In 1870 Republican Governor Edmund J. Davis created three integrated branches of the militia under the Texas Adjutant General (the governor's appointee to oversee the Texas armed forces): the State Police,

the State Guard, and the Reserve Militia. When Democratic candidate Richard Coke won the 1873 gubernatorial election, Davis and black militiamen locked themselves on the first floor of the State Capitol with the vain hope that President Grant would send troops to aid the illegal Republican regime.
The misuse of the militia by what was seen as a tyrannical central (state) government caused a conservative backlash after Davis finally capitulated. Democratic leaders dissolved the State Police and placed renewed emphasis on the local autonomy of militia units. Furthermore, the militias were segregated, part of the conservative Democrat's rolling-back of racial reforms made under Reconstruction. The black militiamen eventually formed an entire separate battalion.

The adjutant general formed a new section of the Texas Rangers, the Frontier Battalion, in 1874 to address the mounting Indian and Mexican conflicts in the wake of withdrawn U.S. Army troops. The return to local militia independence continued until the Texas Militia Act of 1879 restructured and centralized the militia into the more professional Texas Volunteer Guard.[20]

When the United States declared war on Spain in 1898, volunteers across the nation immediately signed for service. Of the four infantry and one cavalry regiments created from the Texas volunteers and militiamen, only one unit, the 1st Texas Volunteer Infantry, received orders to sail for Cuba. Commanded by Woolford Haywood Mabry, who resigned his post as Adjutant General to serve as the commanding colonel of the regiment, the volunteers formed part of the occupation army in Cuba. As militias mobilized for federal service, fear arose among local leaders that the units' county and state identities would vanish.[21] The Spanish-American War served as an act of national reconciliation, which unified the nation for the first time since the devastating 1861-1865 years. As such, the war threatened to undermine the regional and state identities and replace them with a more homogenous American identity. Men from various states and from the northern, western, and southern regions of the United States now saw themselves as Americans united against a common enemy.

In his work on the history of the Texas Militia, Alan Purcell states that the Spanish-American War demonstrated the inefficiencies of the militia system: "it seemed that time had passed the Texas militia by."[22] Certainly any deficiencies in the Texas militia could be traced to a lack of state funding. Even after the war, when the Texas Volunteer Gueard reorganized into a streamlined two brigades of white and one battalion of colored infantry, the Austin legislature only allotted $5,000 to the militia.[23]

Consistent funding would soon arrive for the cash-strapped Texas Volunteer Guard, this time from the national government. However, the money and equipment would come at a price. State authority and local autonomy would have to be sacrificed for the sake of national uniformity, and the militiamen would gradually be absorbed into a larger American system and be recognized more and more as soldiers of the United States. The change in the militias of Texas and other states was a microcosm of what was happening across society as a whole: as the federal government grew in power and oversight, it gradually came to regulate traditional state and local matters. The increasing presence of the national government meant that people came to see themselves more and more as a part of the overall American character rather than as part of states within that overarching system.

A New Federal Standard: Birth of the Texas National Guard

The Spanish-American War had pointed out problems with not only the militias, but also with the regular army, and in 1899 President William McKinley appointed Elihu Root Secretary of War to address the issues. Root's views regarding national and state control are demonstrated in his comments on the future of the militia:

> *An effective army must be built up on the principle of national control. This can never be attained by developing forty-eight different bodies, under officers appointed by forty-eight different*

> *governors, and up to the time of war under the direction of forty-eight different commanders-in-chief.*[24]

Root favored the proposed legislation from Congressman Charles Dick of Ohio, which defined the militia as every able-bodied male citizen between the ages of eighteen and forty-five and divided the militia into three categories: the National Guard, the National Volunteer Reserve, and the Reserve Militia.[25] The state variations on names for the militias (e.g. Texas Volunteer Guard) were to be eliminated in favor of the aforementioned standardized terms, with the wording of the first two proposed forces (National Guard and National Volunteer Reserve) more federal in character. The fact that state militias were to be deemed "National," such as the Texas National Guard, is oxymoronic and points to the new general American identity the men were to assume. As part of a system overseen by the federal government, the men in the militia would naturally come to see themselves as part of a "national" militia system as opposed to a state system.

Men such as John A. Hulen, the new Adjutant General of Texas, supported many aspects of the legislation because it allowed the Secretary of War to allocate money, training, arms, and instructors to the various states; however, tension between advocates of state and national control arose over the National Volunteer Reserve provision of the Dick Militia Act. The provision would have created a uniform reserve force of 100,000 men; consequently, proponents of states' rights feared the new reserve force would usurp the National Guard's position as the number two line of defense behind the regular army.[26] Democrats and labor unions fought off the danger. Nonetheless, the main sections of the act repealing the Uniform Militia Act of 1792 in favor of an unprecedented nationally regulated force of reserves (although still state controlled) passed. Thus was the National Guard born.[27]

Although the militiamen had always served as both soldiers of the state and nation, funding, arms, organization, training, and deployment had always been the prerogative of the various states. That relationship had now changed to a certain degree, and militiamen everywhere would now be forced to answer to a higher, national authority. Although the transformation was not complete, they were now obliged to identify themselves as American soldiers coming from particular states, rather than state soldiers who occasionally served Washington.

Many of the early National Guardsmen saw in the Dick Act the possibility for their expanded participation in national military affairs. An article from the *Los Angeles Daily Times* on September 28, 1909, discussed the 1909 national convention of the National Guard. Many of the attending guardsmen were pressing for a smaller national army with a fully integrated Guard acting as a forty-eight hour, rapid deployment force.

No doubt many of the officers in attendance felt an increase in the Guard's national military responsibilities would enhance their own prestige as well as their operating funds; but at the same time, the desire to be integrated more fully into federal matters might be attributed to the traditional centralist views of the majority of states with representatives present. For, according to the *Los Angeles Herald*, out of all the states present, only two were of the South, the traditional bastion of states' rights.[28] Regardless of the political dispositions of the attendees, all of the guardsmen were walking a fine line between autonomy with federal aid and direct control by the U.S. Army, an act sure to severely reduce their individual powers and more than likely to result in the removal of many of the officers as a streamlined reserve force was created.

Two important events occurred in 1916, making it a paramount year in the continued process of nationalization. First, a standoff took place between the Army and the National Guard. At its most extreme, proposed federal legislation would have effectively eliminated the need for the National Guard by creating a full-time reserve force for the Army; but after much debate, the Hay Preparedness Bill ensured the federal government would further nationalize, not eliminate the National Guard. The

bill passed into law on June 3, 1916, as the National Defense Act of 1916 and called for the transformation of the Guard into a Federal Reserve, supplied, paid, and trained by the United States government.[29] The view was that a strong military force would come from a united, standardized American force, rather than a conglomeration of 48 individual state forces. A united concept of American identity naturally follows from the dissolution of state control, as soldiers start answering to a higher authority and wearing uniforms and patches issued from a national body.

Simultaneously, President Woodrow Wilson mobilized the Texas and National Guard to protect the Mexican border against threats caused by the revolution raging in Mexico since 1910. The first national call came on May 9, a response to the killing of several American soldiers in an attack by Mexican raiders in the Big Bend region. The War Department requested militia from Texas, Arizona, and New Mexico, and 3,762 Texan soldiers headed to the border. The "peacetime" mobilization of the entire Texas National Guard by the President was without precedent and pointed to the ever-tightening federal grip on state sovereignty.[30]

World War I: Formation of the 36th Infantry Division

Rising fear of a German-Mexican alliance following the interception of the Zimmermann telegram led President Wilson to recall the Texas National Guard to border duty in April 1917, after a short hiatus from federal service. Four months later, on August 5, 1917, Washington drafted all members of the Guard into federal service. With the administration of a required federal oath the guardsmen were mustered once again into federal service. The oath served more than a symbolic purpose. It meant that the guardsmen were now legally beholden and financially dependent upon the United States government. It also signaled their entrance into the complicated bureaucratic web of the federal government, as guardsmen having trouble with pension payments for service time would later discover.[31]

Several changes were in store for the National Guards as they headed for training camps around the nation, including reorganizations and a new nationally integrated designation system. Though the army reserved specific divisional numbers for National Guard units, it symbolically eliminated regional identities by prohibiting the former practice of including state names in the new divisional titles. Thus, the army designated the combined Texas-Oklahoma Guards the 36th Division instead of the 1st Texas Division.[32] Different sources contain conflicting accounts about how the 36th Infantry Division came by its new unit number. In his book on the Texas-Oklahoma Division in World War I, *Panthers to Arrowheads*, Lonnie J. White claims the Army originally slated Texas to compose part of the 14th or 15th Divisions, but that a new system with reserved numbers for the Regular Army, National Guard, and National Army meant Texas received the 36th Division designation.[33] However, other sources claim that the Texans specially requested the number 36, presumably in honor of the year of independence from Mexico, 1836.[34] If this were the case, then it certainly speaks something of state pride amongst the new federal troops.

Before embarkation for Europe, the militiamen headed for training at Camp Bowie, Fort Worth. The men of Squad 8, Company C, 5th Texas Infantry kept a unit diary and recorded the "happenings" of their group during training, events during the war, and thoughts after the Armistice. One entry from October 23, 1917, stated the feelings of the Company's historian and his comrades regarding the new number designations (all punctuation and spelling left as found):

> *Old Company 'C' 5th. Tex. Inf. Is now known as Co. M. 143 inf. And we Co. 'C' boys don't like the new name at all. But of coarse we have got to be content with it. Company 'F' 3rd. Texas, also has changed their name to Co. M. 143.*[35]

The above entry might possibly demonstrate the feelings of loyalty that men had to the militia system

bequeathed them from nineteenth century Texas. The numbers and letters symbolized a legacy that could trace its roots back the Republic of Texas, and the men were apprehensive about trading in their old military identities for a new, standardized American one. However, it is equally likely that men set in their ways were simply opposed to change, completely regardless of implications behind such changes.

During the summer of 1918, the division was sent overseas to France where they completed training as part of the American Expeditionary Force. There they participated in the infamous Meuse-Argonne Offensive in 1918, suffering over 2,500 casualties. During the offensive, the 71st Brigade (141st and 142nd Infantry Regiments) participated in the famous Battle of St. Etienne on October 8, in which the two Medals of Honor received by the 36th during the war were earned.[36] On October 10, the entire division saw combat when they relieved the U. S. 2nd Infantry Division, advancing thirteen grueling miles against heavy German resistance, and pushing the Germans to the Aisne River before relief arrived on October 28-29.[37]

Despite the heavy losses, the two-year period of mobilization brought the Texas National Guard into better conformity with national standards and paved the way for the accelerated erosion of state control over the Guard that came during the World War II. In addition to the increased federalization, by the time the division sailed for Texas in May 1919, the extended service away from home helped to undermine the control of the militia by local elites and severe ties with communities.[38] Without local leaders and bosses reinforcing regional, state, and local differences, the guardsmen would begin to see their greater purpose as American soldiers and the similarities they shared with other state guardsmen. This would eliminate perceived differences in state and local identities and start to replace it with a more general American character.

Historians often overlook the militia of the interwar years because the nation's isolationism and pacifism caused widespread opposition to military organizations.[39] Contrary to the rest of the United States military, however, the Texas National Guard expanded to record size and military expertise.[40] Congressional legislation in the early 1920s altered the composition of the United States Army to include the regular army, the National Guard (when in federal service), and the organized reserves. For guardsmen two legislative points caused celebration: first, the relegation over the organized reserve to the number two position in national defense and second, the clause permitting units to maintain "'the names, numbers, and other designations… [from] the World War.'"[41] However, the new statues also provided for stricter federal regulations over National Guard officers and broader controls for the President, allowing him to mobilize the Guard for extended periods of time.[42]

During the interwar years, the national government increased funding on the National Guard, spending approximately $1.5 million per year as well as an additional $5 million on supplies for the Texas Guard compared to the paltry $250,000 allocated per year by the state. As of 1930, Texas was fourth in the country in terms of federal expenditures on state Guards and had the distinction of receiving approval for an Air Squadron by the War Department.[43] Increased spending meant increased federal regulations, and the required conformity to national standards also meant a continued severing of ties between units and their home cities and counties. [44]

The Guard's visibility in local communities also suffered a blow. In the 1920s Texas National Guard companies had been dispatched dozens of times for state-wide law enforcement purposes, but in 1935 the Texas legislature created the Texas Department of Public Safety.[45] Many of the law-enforcement duties heretofore addressed by the National Guard were reallocated and came under the jurisdiction of the new state force and the Texas Rangers. [46] The militia now found itself chiefly providing relief for civil disasters, a growing problem especially in the North Texas oil boomtowns.[47] As far as identity, the soldiers were clearly serving the state of Texas, but the lack of duties and glamour meant that increased federal re-

sponsibilities, especially as World War II approached, were welcome. With war and federalization, however, came a sacrifice to state authority and subsequently of state identity.

World War II: Texans Turned GIs

In August 1940, President Franklin D. Roosevelt signed into law a bill allowing him to call into active service 360,000 guardsmen and reservists for twelve months. His signature put into practice the National Defense Act of 1933 that had both integrated the National Guard into the United States Army and discontinued the law requiring the president to receive approval from the governors in order to activate the National Guards.[48] However, the Act had maintained some semblance of state control by guaranteeing the units would preserve their state identities, meaning they could keep their specific number designations and would be kept intact as fighting Guard units. It also promised the Guards' return to state service at the conclusion to hostilities and ensured Guard officers could retain their posts after the units were mobilized for national service.[49] By keeping Texas guardsmen and officers together, the men were joined by a common bond.

In November 1940, the Texas National Guard, including the 56th Cavalry Brigade and the 12,500 man 36th Division, mobilized for twelve months with the intention of training new conscripts for the regular army. However, when Japanese planes attacked the United States Pacific Fleet at Pearl Harbor on December 7, 1941, the war that had loomed in the distance literally struck home. The enlistment periods were extended indefinitely for the Guardsmen. Congress also revoked laws banning the arbitrary replacement of National Guard officers with those from the regular army.[50] As a result, many political appointees who filled the National Guard officer posts were relieved of duty. Chief of Staff George C. Marshall recognized the importance of state and regional esprit de corps amongst the Guardsmen and ordered the army to seek out new officers amongst the existing ranks of militiamen.[51] If possible, the militias would be led into combat by fellow guardsmen.

The T-Patchers, a name referencing their arrowhead and large "T" divisional insignia, of the 36th Division, under the command of Major General Claude V. Birkhead, assembled at the new Camp Bowie outside of Brownwood, Texas, in December of 1940.[52] During the 1941 training exercises in Texas and Louisiana the army issued Texas National Guard soldiers obsolete weapons at best, broomsticks at worst and prohibited the firing of artillery due to lack of ammunition. Some of the men did not receive arms until they set sail for the Pacific. Also during 1941, the army underwent a structural reorganization from the World War I square divisions to the German triangular model containing three instead of four battalions. One effect on the 36th Division when it finished training at Camp Bowie and maneuvers in Louisiana was the removal of the Second Battalion, 131st Field Artillery—the group destined to become known as the Lost Battalion—and its deployment to the Dutch East Indies.[53]

Despite the reorganizations and lack of equipment, the performance of the guardsmen in U.S. Army training exercises was similar to that of regular army soldiers. A description of the training from a February 1942 news release showed the guardsmen's connection with their Southern roots and the public's general perception of these men as a 'Texas Division': "Epithets were added to rebel yells as the soldiers of the Texas Division jabbed bayonets deep into dummies representing human targets, which they called 'little yellow bellies.'"[54] The National Guard continued to play its peculiarly American role of supplementing the regular army in times of hostility.[55]

On September 13, 1941, during the Louisiana maneuvers, the new policy allowing for the replacement of National Guard officers was put to the test at the highest levels in the Texas Guard when the commander of the 36th Division was removed and Brigadier General Fred L. Walker of Ohio took charge. General Walker anticipated hostility toward a "foreign" command amongst the Texan troops, but the soldiers recognized improved leadership would

probably save lives in the future and approved of the replacement. General Walker simultaneously earned the respect of the men by retaining all of the existing Guard officers, so long as they were deemed competent.[56] Walker led the 36th through their additional training in Florida, North Carolina, and Massachusetts, where they practiced amphibious assaults and stream and river crossing techniques that would prove crucial once they reached Europe.[57]

Through 1943 army postponements of deployment dates plagued the 36th Division and morale began to wane, but finally in March 1943 General Walker received orders for his Division to depart for New York to await transport to North Africa. By April of that year, the 36th Infantry Division would be in French Morocco helping to clear out the remaining German Afrika Korps.[58] The assault on Italy was next.

While the 36th Division trained stateside during early 1941, the War Department ordered the detached Second Battalion, 131st Field Artillery to reinforce the vulnerable Philippines. The decision to deploy the guardsmen in lieu of regular army troops pleased many of the Texans, considering the War Department's past attempts to exclude the Guard from regular military operations. Two direct orders by President Roosevelt, however, demonstrated the national government's true opinion of the National Guard: first, following the December 7th attack on Pearl Harbor, Roosevelt countermanded the Navy's directive for the 131st to return to Hawaii and instead sent them to reinforce the Dutch East Indies, which the military hierarchy considered of only secondary strategic importance; and secondly, while the regular American armed forces evacuated the colony, Roosevelt ordered the 131st to remain, in the face of certain defeat, to display for the press and fellow Allies some attempt to fight. Both the initial removal of the 131st from the 36th Division and their subsequent sacrifice for political motives demonstrate the unchecked power the national government wielded over the state militias during World War II.

After the capitulation of the Dutch on Java, most of the Texans viewed the situation as hopeless. With the exception of a few escapees to Australia, all of the American forces surrendered by March of 1942.[59] Most of the prisoners were eventually shipped to Southeast Asia where dysentery, malnutrition, and tropical diseases exacted a heavy toll on the soldiers as they slaved under vicious Korean guards on the infamous Burma-Thailand Railroad. While forming work battalions, the guardsmen came across another group of Texas prisoners from the sunken *USS Houston*, and they formed a single POW camp under the elected leadership of Colonel Blucher Tharp from Amarillo.[60] Their shared experiences not only linked them together during the war, but also long after, and for many years the Texas men who suffered together in Southeast Asia continued to meet annually in Jacksboro and Wichita Falls.

As the Texas artillerymen were laboring and dying on the Japanese railroad in September 1943, their fellow guardsmen were preparing for an amphibious assault 5500 miles away on the beaches of Italy. According to newspaper accounts, the 36th Division was to be the first American force to land on the European Continent.[61] When asked why the green troops of the 36th had been assigned to lead the invasion of the Europe, the officers of the 36th boasted, "Because it's a Texas division."[62] In the midst of a war in which all American soldiers, whether regular, drafted, Guard, or reserves, were united against a common enemy, the officers chose to identify themselves separately from the other Americans, as Texans, implying that they were tougher and more able. This is a throw-back to perceptions about the rough, independent, frontiersman image generated about Texans during the Republic of Texas.

The Italians had already surrendered, but the Germans were poised for a fight. Quiet blanketed the beaches of Salerno that September 9th. Then an order from the entrenched Germans broke the eerie silence, "Come on in and give up. We have you covered."[63] In an act of defiance, the Texans surged forward waving a large Texas flag emblazoned with the famous words of William B. Travis from the defense of the Alamo, "I shall never surrender or retreat. VICTORY

OR DEATH!"[64] This was not the only example of Texans displaying their unique identity and state pride during World War II. Photographs of soldiers raising Texas flags across the Pacific and Europe appeared frequently in the Texas National Guard's monthly publication.

The Italian campaign resulted in heavy losses amongst the 36th, especially at the two controversial battles of San Pietro and the Rapido River in December 1943 and January 1944 respectively. After the exhausting assault on the town of San Pietro by two of the division's battalions, the 36th was ordered to cross the Rapido River at night in the face of heavy enemy fortifications. They were to pull the Germans away from the Allied beachhead at Anzio.[65] One soldier described the attempted crossing as such:

> *The river was 40 feet wide, and 20 to 30 feet deep, and swift. It had a six-foot bank on each side. The Germans had cleared all the trees and brush and literally laced it with machine-gun fire…We lost two battalion commanders killed, plus all members of their staffs and their company commanders!*

The men of the 36th Division did not retreat, however, they held on at the Rapido River with heavy losses. The wounded and dead mounted to such an extent and German fire kept the medical patrols so pinned down that a temporary armistice had to be called between the Texans and Germans, during which friendly exchanges of food and cigarettes were made. [66]

Major General Walker had fought hard against the plan for a head-on assault that night on the Rapido, but he was overruled from above. The attack failed with casualties in the thousands, and with the 36th scheduled for another direct assault, this time below Villetri in May 1944, Walker again protested. He proposed an alternative plan, "the same old Stonewall Jackson strategy—circle and strike from the flanks and the rear." The first regiment slipped around the German line without firing a shot, and by the next day men from several regiments were three miles behind the town. They then captured the town with surprisingly few casualties as other outfits marched through the gap and on toward Rome.

The Italian battles cost the 36th a tremendous number of men, and only half of the original Texans remained by war's end. Some soldiers, such as E. Douglas Adkins, were lost to capture and sat out the remainder of the war in German prison camps. Congressmen sent letters to the families expressing sympathies, but even in some of these, like the one sent from U. S. Representative Ed Gossett to the family of Adkins, a deeper pride in the 36th and Texas is apparent: "if the name of Texas was not familiar to the Axis, I am sure these boys left them with a desire to avoid the 36th from now on."[67] Even while in a P.O.W. camp, Adkins worried about the future of his division. After hearing rumors that the 36th had been merged with another division he expressed severe disappointment, hoping the 36th would retain its own unique identity.[68]

Despite the losses, however, after participating in the capture of Rome, the 36th was selected as one of three divisions to participate in Operation Anvil-Dragoon, the landings in southern France. In comparison to the bloody Italian campaign, the "French Riviera Campaign" was immensely successful from the start. For 36th Division's part in ridding the French countryside of Nazis, the town of Die in southern France even renamed their main street "Avenue De La Division Du Texas" or "Texas Division Avenue."[69]

The division that assisted in the capture of Rome differed substantially from the outfit that had landed at Salerno in September of 1943. Almost 2,000 men fell establishing the first American beachhead in Europe; another 2,000 casualties were sustained in December at the assault on San Pietro, and 1,500 more were killed or wounded with the controversial attempt to cross the Rapido River in January 1944. This list does not include the men lost at Camino, Summuero, Mount Maggiore, Mount Lungo, Mount Rotundo, and a number of smaller sites in Italy. An article from the *Temple Telegram* stated that out of

Temple's entire Company D, only twenty of the original men were left in the outfit by March 1945.[70]

The high casualty rates transformed the 36th from a division that was about fifty percent Texan to one that contained only 10 to 20 percent native Texans by the time the assault on Villetri occurred.[71] By war's end twenty-seven states were represented in the "Texas" Division, but Texans still held personal claim to the division. An article from May 1944 stated "The 36th division—not an all-Texan outfit any longer but still all Texan in spirit and in victory—is doing a great job in this war…"[72]

As of February 1944, people in Temple were already clamoring for a monument to the 36th and local organizations such as the Elks Lodge were donating money. In April of 1944, permanent organization of the 36th Division Memorial Commission was completed. They initiated the campaign to build a memorial museum for the 36th and following the advice of future Governor Beauford H. Jester, requested the Texas Highway Commission designate Highway 36 from Abilene to Freeport as 36th Division Memorial Highway.

By memorializing the deeds of the 36th, the commission was reinforcing the Texan identity of the guardsmen and also regular citizens, contemporary and future. The state and communities were honoring the guardsmen as heroes, reinforcing their special fighting character; and at the same time, citizens of the communities and state were sharing in the accomplishments of their hometown heroes. For future generations of Texans the accomplishments become part of the greater history of Texas, the mythologized history that sets it apart from other states. Yes they are Americans, but they are Texans too.

By the time of the Nazi capitulation in May 1945, the 36th had fought in six different countries, participated in two major amphibious landings, captured 176,000 enemy soldiers, received 14 Congressional Medals of Honor and six unit citations, and had lost more than 19,000 killed, wounded, or captured.[73] The division also had the distinction of capturing Field Marshall Hermann Goering and Field Marshal Gerd von Rundstedt.[74] The impact on identity can be seen today in the pamphlets and histories that eulogize the events. These were tangible accomplishments that could be called upon as evidence of Texan superiority to the Nazis. It was proof of their unique part in the victory and would ultimately become part of the mythologized history of Texas as well.

The editor of the *Temple Telegram*, Walter R. Humphrey described the feelings of many Texans when he wrote, "The war is coming home to the people Texas as Texas' own heroes begin returning from their part in one of its bitterest conflicts."[75] Such sentiments recognized the unique part Texas played in the history of World War II; that the men and women of Texas State made sacrifices. At the same time, however, by mentioning "their part," the article also deferred to a greater being. Yes Texas played a role in the war as a distinct entity from the United States, but it was still only one state in many whose men wore the American uniform. And another scale, it was one part of a world-wide allied force that ultimately won the war.

Conclusion: Americans and Texans, the Dual Identity

The evolution of the nineteenth-century Texas militias into the modern Texas National Guard fits into a larger historical trend of nationalization in both the public and private sectors. Traditionally, centralization has occurred most rapidly during wars. The Civil War, the Spanish-American War, and World War I all resulted in new legislation that limited the powers of states on a range of issues. This trend heralded the unprecedented federalization of the state militias by Washington in World War II.

Although nationalization formed a large part of the experiences of the Texas Division in World War II, it did not comprise the entire story; there was the overall, homogenous American victory, but encapsulated in that were the individual stories, losses, and victories of distinct National Guard units and men. This duality is probably the most fitting result. The

early Anglo-Americans who settled in antebellum Texas transformed themselves from Americans into Texas frontiersmen, and a century later, in 1940, their great-grandsons transformed from Texans into American soldiers; but in both cases, it was the addition of an identity, not the replacement.

It stands to reason that the tendency toward nationalization would also have resulted in a replacement of regional and state identities with a strictly American one; but at least in the case of Texas, the transformation from "Texan" to "American" was hardly absolute. This might be attributed to the unique history of Texas itself. Why have Texans continued to embrace a state history and identity that in many other states and regions has been swept away by wars, industrialization, depressions, and technological innovation? One answer might be that Texas is in the unique position of having parallel stories for each American legacy: the United States recognizes Plymouth for Thanksgiving, but Texas can claim the first Thanksgiving in North America in 1598 near El Paso; the United States had a War for Independence, but Texas had its own Revolution; whereas the children of the South might have grown-up re-enacting battles of a Civil War they lost, young Texans could look to San Jacinto as a great victory.[76] Most importantly, Texas had its own experience as a nation, an experience embedded in the Texan character and recognized as a fundamental attribute of the Texan identity by both Texans and non-Texans. Over the many decades since Texas has ceased to be an independent country, Texans have nurtured, grown, and exported their State's image as a unique place, both a *state in* and a *state apart* from the United States. The gradual process of Americanization has resulted not in the removal of "Texanness," the sense of uniqueness derived from a mythologized history, but in the emergence of a dual identity, both Texan and American.

From an early period the Texan experience with nationhood was eulogized. It is often said that more books have been written on Texas than on all the other states combined, and certainly when you walk into a bookstore in the State there is likely to be a special section for "Texana." In a way, whether these books seek to expound on the Texan legacy or debunk the Texas "myth," they all help to continue the visibility of Texas and reinforce the perception that Texans are a special group, a group apart.
Throughout the years the definition of a Texan has also changed: early Anglo-settlers adopted components of the Mexican ranching civilization present in the region; the hostilities between the United States and Mexico and the influx of Anglos unfamiliar with the mixed Mexican-Anglo elements of early Texas resulted in the marginalization of Hispanic Texans; and the conservative backlash following Reconstruction eliminated the fledgling integration that had existed in the militia and other forms of society under Republicans rule. There is a definite presence of Hispanic and black Texans, as evidenced by pictures of militia companies, but it is a silent presence overshadowed by Anglo commanders and politicians.

The Texas militia experience was shaped by and shaped the concept of identity. A fluid, dual identity of Texan and American was formed, where the Texan part was another layer of identification that could easily be worn or removed depending on the situation. War, for the most part, served to strengthen the central government as new laws decreased the autonomy of the National Guard, but simultaneously, the Texans sought to better define themselves in the massive new America. The self-definition said, yes we are Americans, but we are Texans also. Depending on the context of the situation, different layers of identification might be invoked. What the experience of the Texas militiamen did demonstrate was that identities are adaptable. The American identity of early settlers in Texas did not disappear during the times of the Republic of Texas, nor did the unique Texas identity based in the mythologized history of the State die during years of federalization; rather they co-existed, and even today form the dual identity of Texan-Americans.

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Thermophilic Chemoautotrophic Arsenite-Oxidizing Bacterium Enriched from the El Tatio Geyser Field, Northern Chile

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Abstract

An enrichment of aerobic, thermophilic, As(III) oxidizing chemoautotrophic bacteria has been established from microbial mats sampled along a transect of the 'Great Geyser' discharge stream in the Middle Basin of the El Tatio Geyser Field, northern Chile. Along this transect, the stream exhibits temperatures ranging from 78°C at the geyser pool to 50°C at the end of the 50 m segment. It is believed that biologically-mediated redox cycling of As occurs along this stream profile and rapid oxidation of As(III) to As(V) (estimated first order kinetic oxidation rate of 0.35 min^{-1} and As(III) half-life of 2 min), was observed both

diurnally and nocturnally. The As(III) oxidizing culture are gram-negative motile rods that were grown chemoautotrophically under aerobic conditions at a constant temperature of 60°C. The minimal basal salts medium contained As(III) as the electron donor, O_2 as the electron acceptor, and CO_2/HCO_3^- as the sole carbon source. HPLC analyses show rapid oxidation of As(III) to As(V) with no noticeable lag period. One millimole of As (III) was completely oxidized within 24 hours. This suggests that As(III) oxidation, coupled with O_2 reduction, drives microbial metabolism and growth; the results thus provide new insight into the diversity of As-mediated microbial activity. Ongoing work is focused on determining the specific growth conditions of these organisms, including the optimal pH, temperature, salinity, and minimum inhibitory concentrations for As(III) and other heavy metal(loid)s. Phylogenetic analyses are also underway.

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Introduction

Arsenic is a carcinogenic metalloid responsible for the contamination of many aquifers throughout the world. One of the most catastrophic examples is the West Bengal and Bangladesh arsenic crisis where millions of people were, and continue to be, exposed to high concentrations of arsenic (As) in drinking water, greater than 300 μg/L in some wells (Chowdhury, 2004). What started as an effort to bring pathogen-free drinking water to rural villages by drilling shallow tube wells and encouraging villagers to switch from polluted river water to, presumably safer, wells throughout India ended with the unexpected poisoning of millions of people. Microbial activity was proposed as a key factor in the contamination of these shallow aquifers (Islam et al., 2004). Where the arsenic comes from, where it goes, and what to do about it are some of the most important problems facing hydrogeologists today.

The concentration of dissolved inorganic arsenic in an aqueous environment is controlled by the particular oxidation state in which it is found. In nature, arsenic can exist in four different oxidation states. Elemental arsenic and arsenide occur only in strongly reducing sediments and will not be discussed in further detail here. In an aqueous environment, dissolved arsenic exists predominantly as arsenite, the reduced form, and arsenate, the oxidized form. Arsenite is a trivalent oxyanion occurring most commonly in reducing environments. It has three equilibrium dissociation constants, or Ka: $Ka_1 \sim 10^{-9.2}$, $Ka_2 \sim 10^{-11}$, and $Ka_3 > 10^{-12}$. This means that at circum-neutral pH arsenite occurs predominantly as $As(OH)_3$. This is represented in the arsenic stability diagram (Figure 1).

Arsenite is considered to have a higher toxicity than arsenate; its tendency to bind to sulfhydryl groups interferes with the proper functioning of many proteins (Oremland et al., 2003). A study done in 2000 showed that human liver cells exposed to arsenite concentrations as low as 1 nM induced DNA-protein cross-links that could be a cause for chromosomal aberrations in cells exposed to arsenite (Ramirez et al., 2000).

Arsenate is a pentavalent oxyanion found predominantly in oxidizing environments. It is considered a weak acid and has three equilibrium dissociation constants with $Ka_1 \sim 10^{-2.24}$, $Ka_2 \sim 10^{-6.94}$, and $Ka_3 > 10^{-11.5}$. Therefore, at pH 7.0, arsenate dissociates into equivalent concentrations of $HAsO_4^{2-}$ and $H_2AsO_4^-$ at 25 °C. Phosphate, which is considered to be a molecular analogue to arsenate, has the chemical formula H_3PO_4, and shares similar structure and acid disassociation patterns. Arsenate's propensity to strongly adsorb onto the surface of minerals such as ferrihydrite and alumina, similar to phosphate, reduces its mobility in a hydrologic environment. As a result, arsenite is considered more mobile than arsenate in an aqueous environment. The close chemical similarity between arsenate and phosphate is the basis for some of its toxicity. When arsenate enters a cell it inhibits oxidative phosphorylation which in turn impedes the ability of the cell to generate ATP (Oremland et al., 2003).

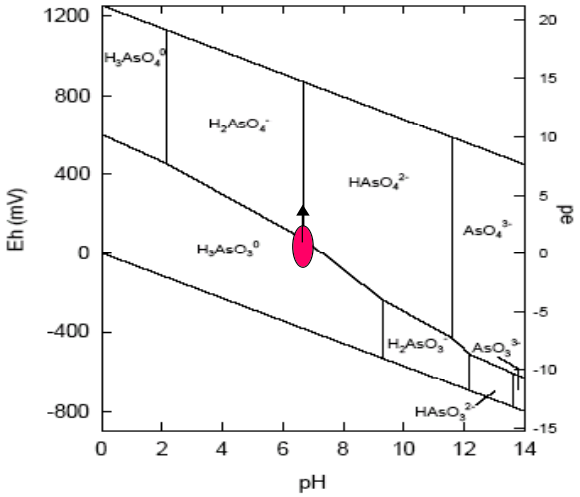
The biological and environmental effects caused by the mobilization of arsenic into groundwater systems have been intensively studied. As illustrated in equation 1, the oxidation of arsenite to arsenate is an exergonic chemical reaction (Santini et al., 2000).

$$2H_3AsO_3 + O_2 \rightarrow HAsO_4^{2-} + H_2AsO_4^- + 3H^+$$
$$(\Delta G^{0'} = -256 \text{ kJ/Rx}) \quad \text{(Figure 1)}$$

However, in the absence of a catalyst, this reaction occurs at an extremely low rate abiotically. Bacteria are suspected of driving this reaction, though their role is not fully understood. By changing arsenic from one oxidation state to another, for example arsenite to arsenate, microbes may impact the mobilization of arsenic within a system as well as the toxicity.

Prokaryotes gain energy from a variety of different metabolic processes. The ability of microbes to metabolize arsenic was discovered in 1918 when Green (1918) isolated arsenite-oxidizing bacteria

Figure 1 *This diagram (Landrum, 2007) delineates the relative stabilities of arsenic species in an aqueous environment at 60 °C. The highlighted area represents the El Tatio hydrothermal waters. The arrow represents the change that occurs during arsenite oxidation.*



Jennifer Denbow

from a cattle-dipping tank. Since then an increased effort has been made to describe and characterize other micro-organisms with this same metabolic capability (Oremland et al., 2003).

The observed rapid arsenite oxidation in the El Tatio waters (Landrum, 2007) is suggestive of biotic influence, but there were no previous attempts to culture and isolate potential arsenite-oxidizing microbes from the site. Here I provide evidence that biotic arsenite oxidation occurs at the El Tatio Geyser Field.

Site Description

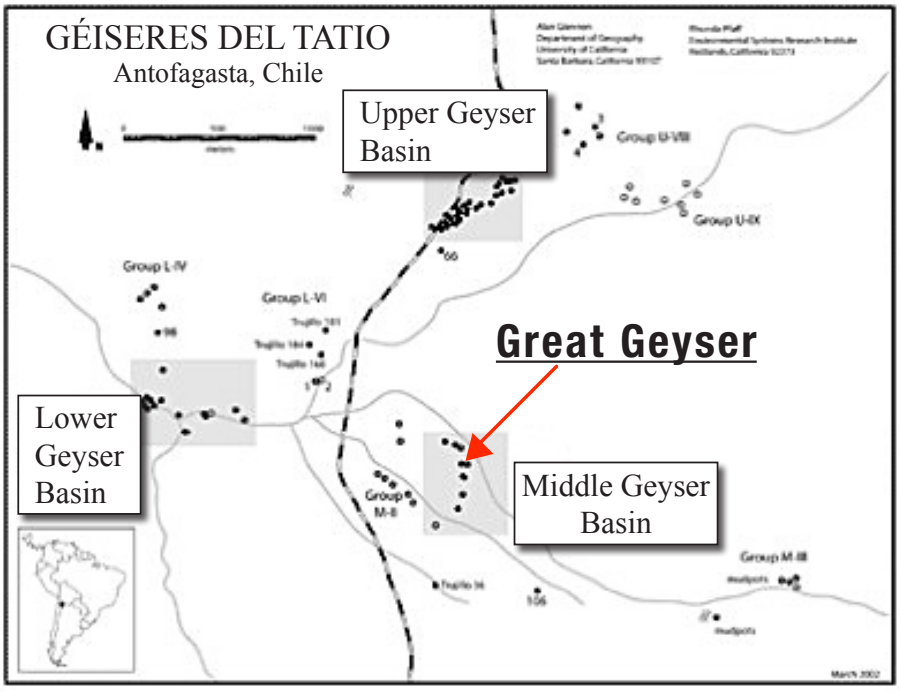
The El Tatio Geyser Field is located in the hyper-arid Atacama Desert in northern Chile (Figure 2). The hydrothermal waters at the sampling site are characterized by circum-neutral pH (ranging from 6.5 to 7), high salinity, low dissolved inorganic carbon (0.1 to 0.5 mM TIC), and very high concentrations of naturally occurring As (III) that range from 346 to 603 µM ∑As. The uniquely high dissolved arsenic concentration makes this an ideal location for putative arsenite-oxidizing bacteria.

Methods - Preliminary Experiments

In the fall of 2006, I performed three experiments with frozen samples to determine an appropriate enrichment broth and a methodology that could be applied to later experiments done with fresh samples collected in December 2006. Specifically, I examined: (1) Whether frozen samples could be cultured, (2) the effects of arsenic on the cultures, and (3) an optimal media for culturing with arsenic. The results from this line of research led me to develop different techniques for the freshly collected samples in December 2007. These more recent analyses, their results and implications, form the principal focus of this thesis and are described in greater detail later in the text.

The microbial mat samples for the preliminary experiments were collected in 2005 by the Bennett

Figure 2 — *Map of the El Tatio Geyser Field in northern Chile (Glennon and Pfaff, 2003). Microbial mat samples used to enrich chemoautotrophic growth were collected from the 'Great Geyser' (arrow) located in the Middle Geyser Basin.*



experiments were collected in 2005 by the Bennett Research Group from the El Tatio Geyser Field and stored frozen (-80 °C) in the Geology Department at the University of Texas at Austin. A list of the sample identification codes and the available provenance data for the samples used in the following experiments is provided in Table 1 below.

Experiment 1

The purpose of the first experiment was to determine whether any of the frozen 2005 samples of microbial mat could be cultured. In order to do this, samples were placed into a minimal basal salts enrichment medium (Table 2) developed by Gihring et al. (2005). This medium will be referred to as Medium A throughout the rest of the paper.

Enrichment Medium A was dispersed in 50 mL aliquots into 70 mL serum bottles, which were then sealed with sponge stoppers and autoclaved for one hour at 122 ºC. Pea size globules of each sample were used as inoculum, for three replicate bottles, with the exception of the sterile control. All bottles were kept in the dark on a shaking incubator (125 rpm) for one week. The incubation temperature was started at 25 ºC and incrementally increased over the following three days to a final temperature of 60 ºC. At the end of one week, I quantified and described the biomass in each bottle. The most productive culture (based on the quantity of biomass within the bottle) from each triplicate set was chosen as the inoculum to be used in Experiments 2 and 3.

Experiment 2

The purpose of Experiment 2 was to determine the effect of arsenic on bacterial growth in the enrichment cultures established in Experiment 1. The enrichment Medium A was dispersed in 10 mL aliquots into 22 mL MPN tubes and autoclaved for 40 minutes at 122 ºC. The tubes were then divided into two groups. One group received a sterile addition of sodium arsenite, achieving a final concentration of $NaAsO_2$ (1mM). The second group received a 0.5 mL sterile addition of NaCl (23mM) instead of sodium arsenite. For simplicity, the media that received arsenite is denoted as Medium B; the media that received NaCl is denoted as Medium C.

One milliliter of enrichment culture from Samples 1-5 in Experiment 1, as well as a globule of microbial mat taken from Sample 6, that had been cultured in Experiment 1, were inoculated into new tubes containing Medium B and Medium C. After inoculation, the samples were incubated in the dark at 60 ºC. There were two replicates done of each sample plus both a sterile and a killed control. All killed controls were autoclaved for 45 minutes at 122 ºC after the addition of inoculum.

Experiment 3

The purpose of Experiment 3 was to optimize the methodology in Experiment 2 using a media containing lower yeast and higher salt concentrations in order to see whether this would produce a difference in growth patterns. The yeast concentration in the medium was decreased from 2% w/v to 0.5% w/v and the salt concentration was increased to 3.5 g/L. The modified media containing arsenite is denoted as Medium D and the modified media that received NaCl instead of arsenite is denoted as Medium E.

Methods- Chemoautotrophic Growth

The procedures developed for this experiment were designed to isolate thermophilic chemoautotrophic arsenic-oxidizing microbes from the geyser waters. These methods were developed in collaboration with Shelley Hoeft and Ron Oremland, (USGS, Menlo Park, CA) both experts in the ecology of arsenic. The two major goals for this research were to determine whether the thermophilic community in the El Tatio hot springs accelerates the oxidation of arsenite and to enrich these organisms and isolate them as a pure culture.

For the enrichment process I used microbial mat samples collected in December 2006 by members of the Bennett Research Group. These samples were collected every 10 meters along a 50-meter transect of the 'Great Geyser' discharge stream (Figure 4). Along

Table 1 | Sample Inventory

Sample ID	Shortened ID (For the purpose of this paper)	Type	Color	Description
TAT05–03011 B1	1	Unknown	Unknown	Unknown
1/7 TAT05–Matt – J3 – 001	2	Microbial Mat	Greenish Brown	Mushy and oderiferous (An image file exists)
TAT05–Mat – 012	3	Microbial Mat	Light Grey	Filamentous and Stringy
TAT05 A5	4	Unknown	Unknown	Unknown
TAT03 – X	5	Unknown	Unknown	Unknown
TAT05 1/7 crusted biofilm	6	Mat/ Solid	Orange, white	Floating orange mat in El Tatio water

Table 2 | *The constituents of enrichment Medium A. After preparation this medium was adjusted to pH 7.5 with NaOH.*

Name	Chemical Formula	Grams per Liter
Magnesium Sulfate, 7-Hydrate	$MgSO_4 \cdot 7H_2O$	0.18
Ammonium Sulfate	$(NH_4)_2SO_4$	0.8
Potassium Phosphate Monobasic	KH_2PO_4	0.4
Sodium Chloride	NaCl	1.75
Yeast extract	*n/a*	20

this transect, the stream exhibits temperatures ranging from 78 ºC at the mouth of the geyser discharge to 50 ºC at the end of the segment. The microbial mat samples were collected using sterile techniques and transferred into sterile 50 mL falcon tubes which where then immersed in native water collected from just above the mat.

Enrichment and Isolation

The initial enrichment medium was based on the growth medium used for the isolation of *Thermus thermophilus* and *Thermus aquaticus* (Gihring et al., 2001). The medium was modified, however, to meet the conditions of the sampling environment and to enrich for chemoautotrophic growth. The final enrichment medium contained the compounds and quantities shown in Table 3.

In addition to these compounds, the following trace minerals (Table 4) were added to the enrichment medium from a 1000-fold concentrated solution prepared according to the procedure described by Kuia and Poltz (2001).

The final enrichment medium was dispersed in 18 mL aliquots into 70 mL serum bottles, which were sealed with Bellco rubber stoppers and autoclaved for 40 minutes at 122 ºC. Filter sterilized stock of $NaHCO_3$ (1 M) and $NaAsO_2$ (100 mM), which was prepared in advance, was then used to make sterile additions to the bottles after autoclaving. In this way, a final concentration of $NaHCO_3$ (17.5 mM) and $NaAsO_2$ (1 mM) was achieved in each bottle.

Each 70 mL serum bottle was inoculated with 2 mL of microbial mat suspended in native water and incubated in the dark for one week at 60

ºC before being transferred into fresh medium. Once all of the initial arsenite was oxidized (determined using HPLC), sterile $NaAsO_2$ was added to maintain growth. Two milliliters of enrichment culture was sub-sampled every 1 to 4 weeks into fresh medium in order to: (1) gradually eliminate any organic carbon that might be present in the bottles from mat material in the initial inoculation, and (2) prevent the closed sample environment from reaching toxic levels resulting from the sterile arsenic additions.

Each 70 mL serum bottle was flushed daily with a 20 % CO_2 (80% air) mixture. The O_2 was added to maintain an aerobic environment, with CO_2 added to buffer the pH and to provide a source of inorganic carbon for autotrophic growth. A 60 mL syringe was filled with 12 mL of CO_2 and 48 mL of air; this was injected into the serum bottle through a 0.2 µm filter. This process was repeated to ensure that the entire headspace of the bottles had been flushed. Gas Chromatography (GC) was used to analyze the gas in the headspace. The results showed that flushing was only necessary bi-weekly.

To obtain a pure culture, 10 µL of media taken from the enrichment cultures was streaked onto a solid plate medium composed of the enrichment medium with additions of Wolfe's vitamins (10 mL/L) and Gelrite (Sigma) (10 g/L). After autoclaving, the medium was sparged with CO_2 before being poured into solid plates. The plates were incubated at 60 ºC for one week. Individual colonies were then plucked off of the plates and transferred to the initial liquid enrichment medium described above. The resulting cultures were incubated in the dark at 60 ºC.

Table 3 *The constituents of the minimal basal salt enrichment media.*

Name	Chemical Formula	Grams per Liter
Magnesium Sulfate, 7-Hydrate	$MgSO_4 \cdot 7H_2O$	0.18
Ammonium Sulfate	$(NH_4)_2SO_4$	0.8
Magnesium Chloride, 6-Hydrate	$MgCl_2 \cdot 6H_2O$	1.2
Potassium Phosphate	K_2HPO_4	0.225
Potassium Phosphate Monobasic	KH_2PO_4	0.225
Sodium Chloride	NaCl	3.5

Table 3 *Trace minerals added to the enrichment medium.*

Name	Chemical Formula	Milligrams per Liter
Manganese dichloride, 4-Hydrate	$MnCl_2 \cdot 4H_2O$	0.1
Cobalt chloride, 6-Hydrate	$CoCl_2 \cdot 6H_2O$	0.12
Zinc chloride	$ZnCl_2$	0.07
Boric acid	H_3BO_3	0.06
Nickel (II) Chloride, 6-Hydrate	$NiCl_2 \cdot 6H_2O$	0.025
Copper Chloride, 2-Hydride	$CuCl_2 \cdot 2H_2O$	0.015
Sodium Molybdate, 2-Hydride	$Na_2MoO_4 \cdot 2H_2O$	0.025
Ferrous Chloride, 4-Hydrate	$FeCl_2 \cdot 4H_2O$	1.5

Analytical methods

For the experiments carried out at the USGS Biogeochemistry lab arsenite oxidation was determined using HPLC (Culbertson et al., 1988) modified by the addition of a Hamilton PRP-X300, 15 by 0.41 cm, column with a 16 mN H_2SO_4 eluent (Laverman et al., 1995). For experiments carried out at the UT-Geomicrobiology lab arsenite oxidation was monitored using the HPLC UV/Vis method described by Rubio et al. (1993). This method separates arsenic species on a Hamilton PRP-X100, 250 mm by 4.1 mm, strong anion exchange column with a 25 mM phosphate buffer as the mobile phase. Arsenic species are detected by UV absorption on a Waters 476 spectrophotometeric detector. Peak areas were calculated using PeakSimple software with external calibration.

Results - Preliminary Experiments

The microbial mat samples from the 2005 expedition used for inoculation ranged in color from reddish orange-brown to a murky green. The samples used for inoculation were taken from a variety of locations in the geyser field, with potentially differing environmental parameters. Turbulence within the enrichment cultures inoculated with microbial mat samples was apparent two days after inoculation. The samples began to grow biofilms on the fourth day. When the samples were transferred into fresh media from the existing enrichment culture, growth was visible within 24 hours. The results of Experiments 1, 2, and 3 for each of the six mat samples are described below.

Microscopy and Gram Staining

With the use of phase contrast microscopy

Figure 3 — *The data for this chart represent the average optical density of enrichment cultures incubated in Media B (with arsenic) and C (in a more saline environment without arsenic)*

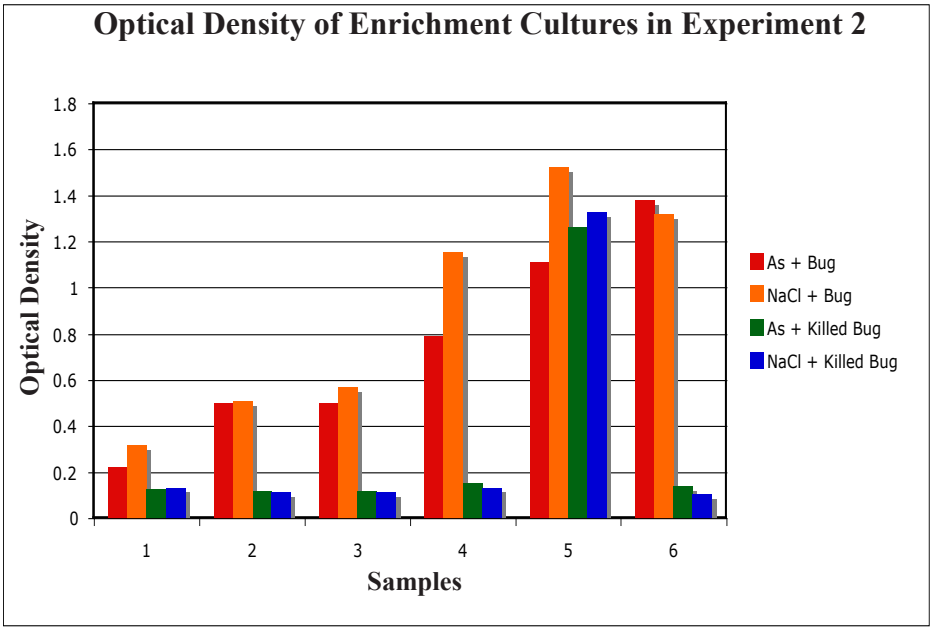
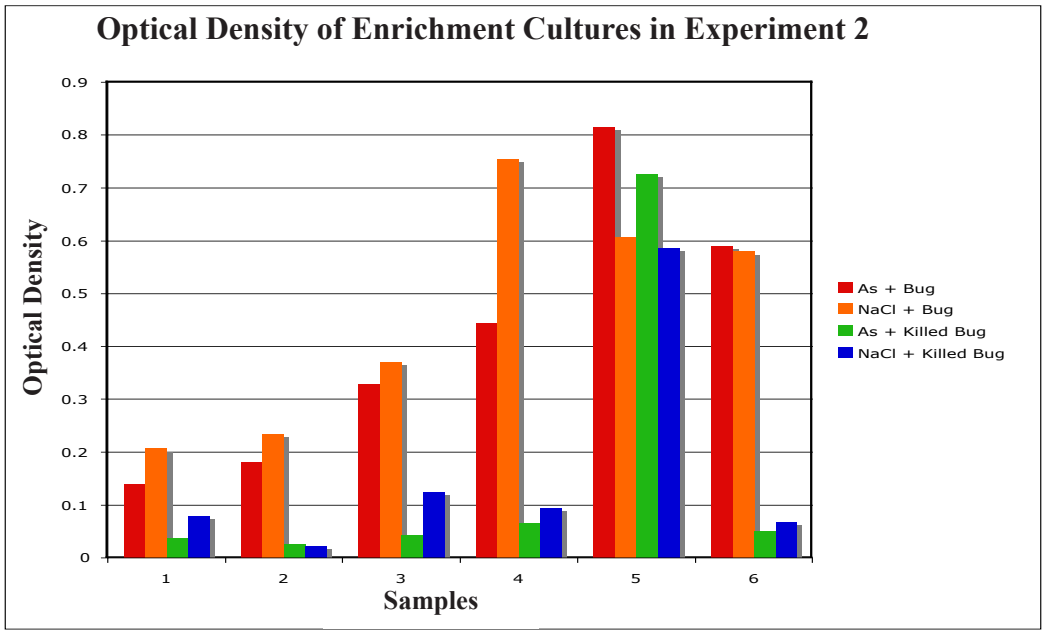


Figure 4 Figure 4: This chart represents the average optical density of enrichment cultures incubated in Media D (in a less saline environment with arsenic) and Media E (in a more saline environment without arsenic)



and gram staining techniques, the enrichment cultures from samples one through six were found to consist of a community of gram negative motile bacillus prokaryotes with a length of approximately 1µm.

Culture assessment

The optical density of each enrichment culture developed in Experiments 2 and 3 was measured at the end of the incubation period in order to more precisely compare microbial productivity for samples grown in the high yeast and low yeast environments, and with and without the presence of arsenic. Samples 1-5 grew better in higher saline environments in the absence of arsenic (Figure 3). Sample number 6 grew better in a less saline environment in the presence of arsenic. As mentioned above, the Sample 5 killed control also grew marginally better in the absence of arsenic with a more saline environment.

When grown in Media D and E enriched with arsenite and NaCl, respectively, the killed control for Sample 5 again behaved differently from all of the others (Figure 4). This sample also had the highest productivity in the less saline arsenic-rich environment, although growth was almost as good in the higher saline non-arsenic environment.

Results- Chemoautotrophic Growth

The microbial mat samples from the 2006 expedition that were used for inoculation ranged in color from reddish-brown to orange-brown. Phase contrast microscopy and gram staining determined that these isolates are a strain of gram negative, motile, rod shaped prokaryotes with a length of approximately 1µm. These chemoautotrophs were grown aerobically in a minimal basal salts medium that contained arsenite as the electron donor, oxygen as the electron

acceptor, and carbon dioxide and bicarbonate as the sole carbon source. When grown on plates these microbes have a pale yellow pigmentation. In liquid solution, they show little to no visible turbidity.

Arsenite oxidation assay

Enrichment cultures showed rapid arsenite oxidation relative to the abiotic control (Figures 6,7,8). Two microbial mat samples were tested for arsenite oxidation, the first from the start of the sampling transect at the mouth of the 'Great Geyser' and the second from ~ 50 m away (Figure 6,7). The microbial mat used to inoculate the medium shown in Figure 6 was taken from the end of the sampling transect ~ 50 m away from the mouth of the 'Great Geyser.' While both samples oxidized arsenite to arsenate (Figure 6,7), the process was more rapid in the second location. Additional arsenite was added to "feed" the enrichment (circled in red) once for the first sample and twice for the second sample over the course of the experiment.

Arsenite oxidation rate

The experiments described above indicate that arsenite oxidation rates were much higher in inoculated samples (Figures 6 and 7) than in the abiotic control (Figure 8) where little to no oxidation occurred. In addition, once established in the enrichment media, the microbes enriched from samples taken at the end of the sampling transect were able to completely oxidize arsenite at a rate of 1mmol/ day. As a result of sterile additions of arsenite to the enrichment cultures concentrations of up to 7mM of arsenic were established in some of the bottles. Arsenite oxidation, however, continued at a consistent rate despite the extremely high concentrations of arsenic that

Figure 5 — *Data from the most productive duplicate for Samples 1-6 from Experiments 1 and 2 are illustrated on this chart. In the presence or absence of arsenic, yeast had a positive effect on microbial growth, particularly in Samples 4, 5, and 6 (Figure 5)*

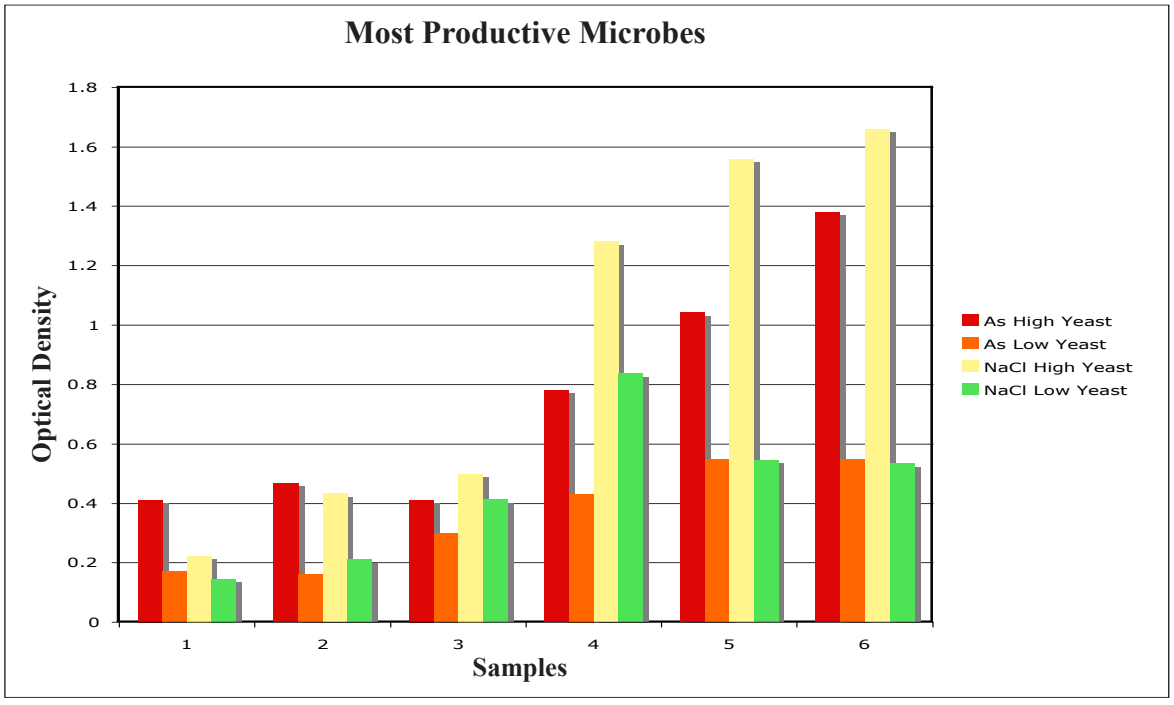


Figure 6 Plot showing the rapid oxidation of arsenite to arsenate. The deviation circled in red represents the point where a sterile addition of arsenite was injected in order to maintain growth.

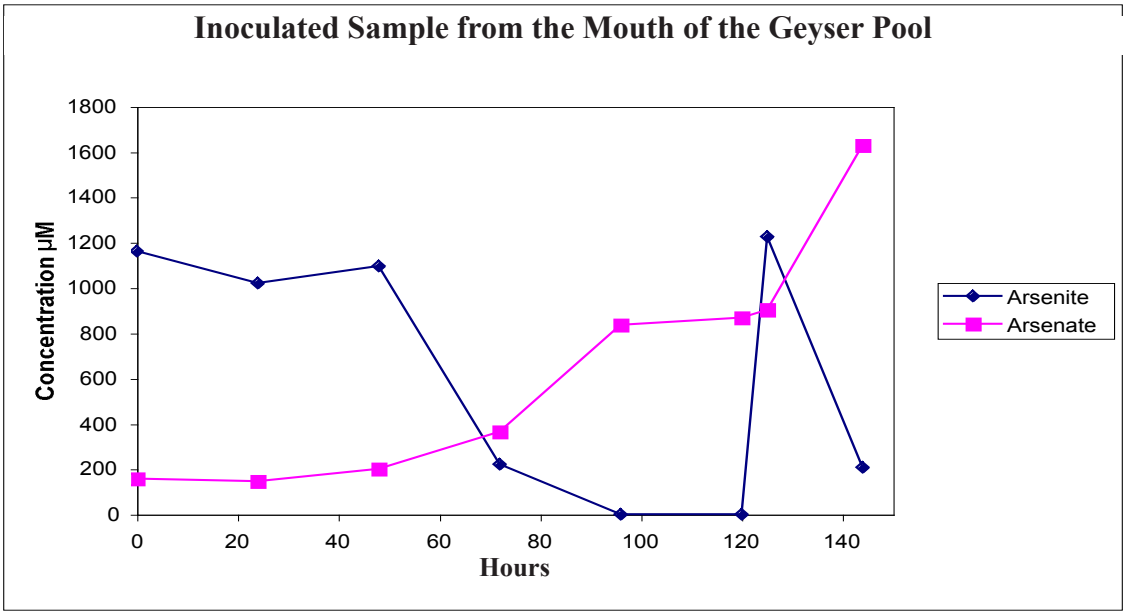
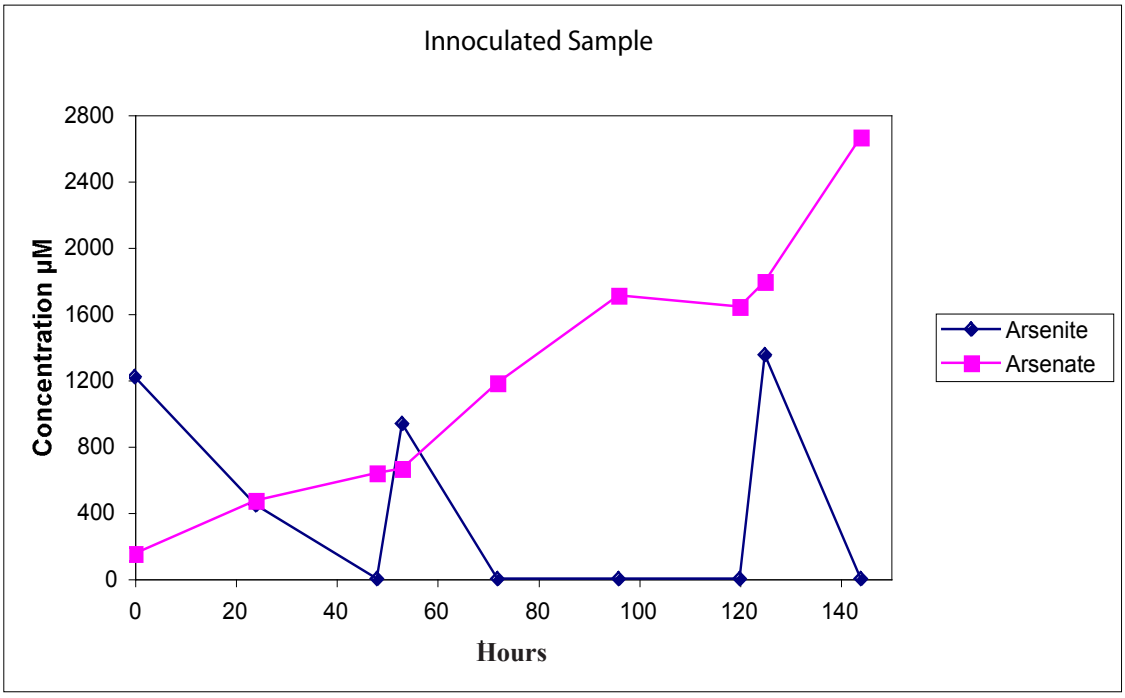


Figure 7 Plot showing the rapid oxidation of arsenite to arsenate.



resulted. No maximum or minimum arsenic concentrations for growth were established.

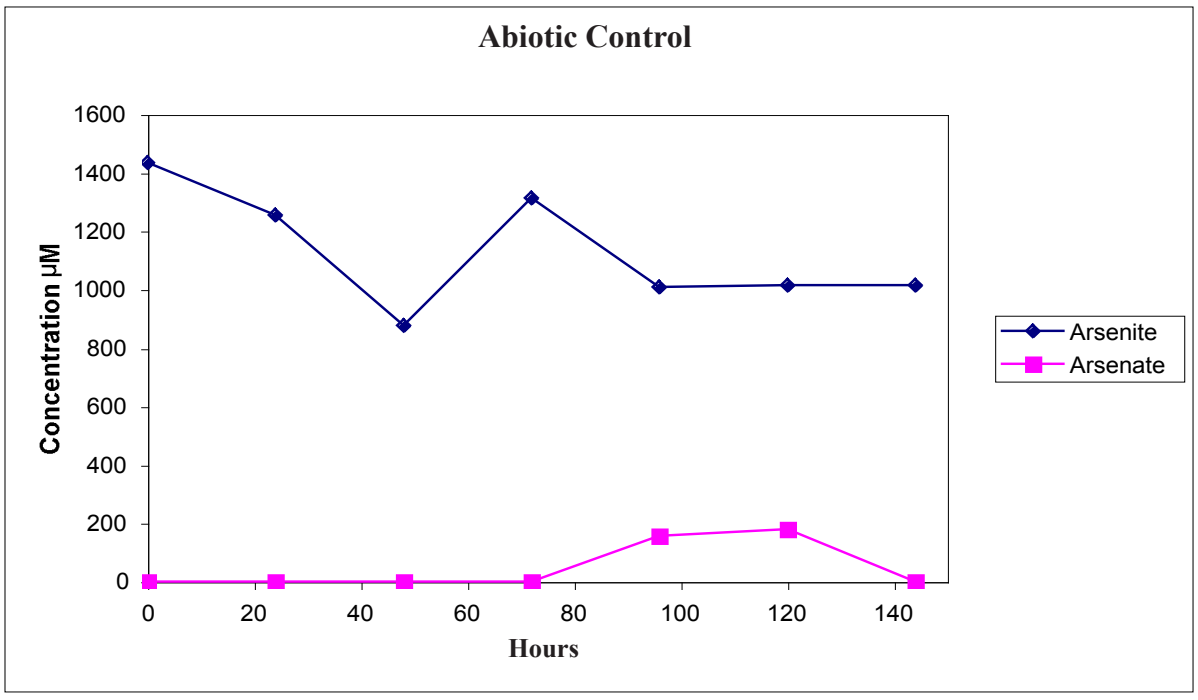
Arsenite oxidation initially occurred much more rapidly in the enrichment culture inoculated from samples collected at the end of the sampling transect most distant from the geyser mouth. These samples came from hydrothermal waters with a temperature of ~50 °C. Samples collected in the warmer waters near the geyser mouth, on the other hand, initially showed less rapid arsenite oxidation rates. This could be because the experiment was conducted at 60 °C, a temperature that may have been too cool for optimum growth of organisms adapted to higher temperatures (~70 °C) nearer the Geyser mouth. On the other hand, the slower growth rate, based on the extremely low biomass produced, might also indicate that the media used was missing some important component and therefore did not provide an optimal environment for growth.

Discussion - Preliminary Experiments

The killed controls for Sample 5 showed microbial activity in both Experiments 2 and 3. This suggests that the microbes enriched from this microbial mat sample were either extremely thermophilic microbes that can survive sustained temperatures of 122 ºC for 45 minutes, or these microbes produce endospores that are able to survive under such conditions. I do not think contamination is the best explanation because no sterile controls, and no other killed controls (n=44) prepared at the same time, showed signs of microbial growth.

The presence of an extremely hardy, hyperthermophilic organism is possible, but unlikely. Currently, the highest temperature at which such an organism has been described to live at is 'Strain 121', a hyperthermophilic chemoautotrophic Fe(III)-reducing microbe. Strain 121 was isolated from an autoclave and, according to Kashefi and Lovely (2003), is capable of growing in temperatures be-

Figure 8 | *Plot showing the rapid oxidation of arsenite to arsenate.*



tween 90 ºC and 113 ºC which is below the autoclave temperature used in my experiments.

A final possibility is that microbial endospores were unknowingly present in this particular sample. Endospores are special structures formed within a cell that are extremely resistant to harsh environments and can remain dormant for long periods of time. They are extremely tolerant of heat and can survive the presence of harsh chemicals. They are only formed by gram positive bacteria, and all of the samples in this experiment had a negative reaction to gram staining. Although it is possible for the gram staining procedure to yield a false negative if the sample is rinsed with ethanol for too long after washing off the crystal violet stain, for the moment the explanation for the growth in the killed sample remains anomalous.

Culture assessment

The results from the optical density assay show that microbes in the enrichment culture grew better in media containing higher concentrations of yeast (Figure 5). Productivity was assessed indirectly, however, by measuring the optical density of the samples against a blank containing the initial medium. One problem with this technique is that samples that grew more cohesively in visual accumulations or clumps, as opposed to those that exhibited more pervasive turbidity, produced lower optical density measurements despite the fact that they contained a greater quantity of biomass. This is because the spectrophotometer measures scattered light (the light that is not absorbed by the sample). A cluster of cells will absorb less light than the same number of cells floating freely in a matrix because the latter will have a greater surface area to absorb light. Therefore, biomass productivity as measured indirectly by optical density was deemed an insufficient method for reliable comparisons of microbial growth for samples of varying growth patterns (i.e., homogenous turbidity vs. clumps of cells).

Discussion - Chemolithoautotroph

The experimental data indicate that the oxidation of arsenite to arsenate in the enrichment cultures was greatly accelerated by the metabolism of the inoculated micro-organisms – little to no oxidation occurred in the non-inoculated control samples (Figures 6,7,8). From these experiments it is not clear if it was one or several different populations that contributed to the increased rate of oxidation.

The results therefore suggest that the increased rate of arsenite oxidation observed in the inoculated samples is due to the presence of viable arsenite oxidizing microbes because the oxidation rate in the inoculated samples was much higher than in the abiotic control, and the inoculated bottles in which microbes did not survive (the killed control substitute) showed no increase in arsenite oxidation rate when compared to the abiotic control. Phase contrast microscopy confirmed these findings by verifying that the bottles with dead samples contained no living, active microbial communities, while the inoculated live bottles contained an abundance of mobile microbes. The results thus support the hypothesis that the arsenite oxidation observed was not just a chemical reaction between the media and the microbial cells, but rather was due to microbial metabolism.

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